PB-216 757

WATER RESOURCES STUDY AND PUBLIC HEALTH ASPECTS OF THE JEFFERSON AND WHITEHALL UNITS THREE FORKS DIVISION MISSOURI RIVER BASIN PROJECT MONTANA

Public Health Service
Denver, Colorado

April 1964

DISTRIBUTED BY:

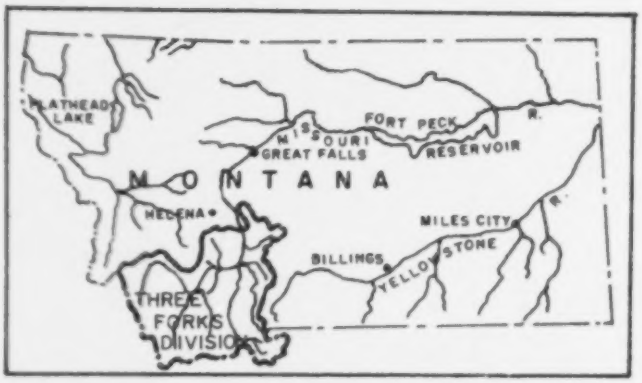
NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

HE 20.2 : m69 o/8

PB 216 757

WATER RESOURCES STUDY
and
PUBLIC HEALTH ASPECTS
of the
JEFFERSON AND WHITEHALL UNITS
THREE FORKS DIVISION
MISSOURI RIVER BASIN PROJECT
MONTANA



NATIONAL TECHNICAL INFORMATION SERVICE

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE, REGION VIII
DENVER, COLORADO

APRIL 1964

68

HE 20.2:	U.S. HEW Public Health Service General publications
H 69 o/8	Water resources study and public health aspects of Jefferson and Whitehall units, Three Forks Division, Missouri River basin project, Montana, study of potential needs and value of water for purpose of water quality control and public health aspects of Jefferson and Whitehall Units, Three Forks Division, Missouri River Basin Project, Montana [with bibliography]. Denver, Colo., April 1964. (Region 8; Division of Water Supply and Pollution Control.) [Prepared at request of and in cooperation with Bureau of Reclamation, Region 6, U.S. Department of Interior, Billings, Mont.] (no ID number)

WATER RESOURCES STUDY
and
PUBLIC HEALTH ASPECTS
of the
JEFFERSON AND WHITEHALL UNITS
THREE FORKS DIVISION
MISSOURI RIVER BASIN PROJECT
MONTANA

Study of potential needs and value of water for the purpose of water quality control and the public health aspects of the Jefferson and Whitehall Units, Three Forks Division, Missouri River Basin Project, Montana

Prepared at the request of and in cooperation with the Bureau of Reclamation, Region 6, U. S. Department of the Interior, Billings, Montana

U. S. Department of Health, Education, and Welfare
Public Health Service
Division of Water Supply and Pollution Control
Region VIII
Denver, Colorado

APRIL 1964

TABLE OF CONTENTS

	Page
TABLES	v
FIGURES	vi
INTRODUCTION	
Authority and Request	1
Purpose and Scope	1
Acknowledgements	2
PART A - WATER RESOURCES STUDY	
I. SUMMARY AND CONCLUSIONS	
Summary	3
Conclusions	3
II. PROPOSED DEVELOPMENT AND DESCRIPTION OF STUDY AREA	
Proposed Project Development	5
Description of Study Area	6
Location	6
Boundaries	6
Soils	7
Drainage	7
Salinity and Alkalinity	7
Topography	8
Climate	8
Transportation	8
Principal Trade Centers	8

TABLE OF CONTENTS (Continued)

III. THE ECONOMY

General Economic Setting 9

Industrial Employment and Population Trends 10

Agriculture 10

Mining 10

Forestry 12

Manufacturing 12

Service Industries 13

Population Trends 13

Economic Outlook: Employment and Population 13

IV. WATER SUPPLY

Ground Water 17

Surface Water 18

Quality 18

Mineral 18

Sanitary 21

State Standards 21

Uses 21

Fish and Aquatic Life 23

Future Municipal and Industrial Water Requirements 23

V. MINIMUM STREAMFLOW REQUIREMENTS

Sources of Pollution 24

Stream Quality Maintenance 24

TABLE OF CONTENTS (Continued)

Streamflow Requirements 26

Municipal Waste Waters 26

Industrial Waste Waters 27

Mineral Quality 30

VI. ECONOMIC BENEFITS

PART B - PUBLIC HEALTH ASPECTS

I. SUMMARY AND RECOMMENDATIONS

Summary 33

Recommendations 33

II. PUBLIC HEALTH AND RELATED PROBLEMS

Public Health Services 36

Recreational Development 36

Construction Phase of Project 36

Sanitary Aspects of Watershed Management 37

Preliminary Vector Evaluation 37

Anticipated Effects of the Proposed Project on Vector Problems 37

Responsibility for Vector Control 39

BIBLIOGRAPHY

APPENDICES

TABLES

Number	Title	Page
1	Industrial Employment and Location Quotients 1940, 1950, and 1960	11
2	Industrial Employment and Population, 1940, 1950, 1960, and Forecasts for 2010 and 2060	14
3	Streamflow Data (USGS)	19
4	Chemical Quality of Surface Waters	20
5	Municipal Water Supplies	22
6	Sources of Pollution	25
7	Concentration of Total Dissolved Solids and Annual Salt Load	31

FIGURES

Number	Title	Page
1	Location Map	Preceding back cover
2	Population - Jefferson-Whitehall Unit . . .	Following page 16

INTRODUCTION

Authority and Request

In a letter dated October 24, 1961, the Bureau of Reclamation, Region 6, Billings, Montana, requested the Public Health Service to determine the need for and value of water to be stored in Reichle Reservoir of the Jefferson Unit for regulation of streamflow for the purpose of water quality control. This request was subsequently expanded by a letter of August 10, 1962, from the Bureau to include the Whitehall Unit.

This study has been made under the provisions of the Federal Water Pollution Control Act, Public Law 84-660 as amended by Public Law 87-88. Under these provisions consideration must be given, in the survey or planning of any reservoir by a Federal agency, to inclusion of storage for regulation of streamflow for the purpose of water quality control. Storage and release of such water is not to be provided as a substitute for adequate treatment or other method of controlling waste at their sources.

Purpose and Scope

General objectives of this study are to assess the probable effects of project construction and operation on water quality in local streams and reservoirs, to ascertain the benefits or harm resulting from changes in water quality, and to examine the need for regulation of streamflow for the purpose of water quality control in the principal streams affected. Need for regulation of streamflow was studied not only in light of present conditions, but also under anticipated economic development of the years 1985, 2010, and 2060.

The report also includes the results of a study of general public health aspects and insect vector control of the project. The insect vector control section, prepared jointly by the Montana State Board of Health, and the Communicable Disease Center, Public Health Service, Greeley, Colorado, presents a preliminary evaluation of the insect vector problems that may be associated with the development of the Jefferson and Whitehall Irrigation Units.

Acknowledgements

The assistance and cooperation of the various State and Federal agencies and individuals are gratefully acknowledged by the Public Health Service. Particular appreciation is expressed to the following for data and advice furnished by their staff members:

U. S. Bureau of Reclamation, Region 6
Billings, Montana

U. S. Bureau of Reclamation, Upper Missouri
River Projects Office, Great Falls, Montana

U. S. Bureau of Land Management, Lands and
Minerals Management Division
Billings, Montana

U. S. Forestry Service, Missoula, Montana,
and Ogden, Utah

Montana School of Mines, Butte, Montana

School of Forestry, University of Montana
Missoula, Montana

Bureau of Business Research, University of Montana
Missoula, Montana

Montana State Board of Health, Helena, Montana

Montana State Unemployment Compensation Commission
Helena, Montana

Montana State Department of Agriculture
Helena, Montana

Montana State Planning Board, Helena, Montana

Montana State Engineers, Helena, Montana

Montana State Fish and Game Department
Helena, Montana

Montana State Water Conservation Board
Helena, Montana

PART A - WATER RESOURCES STUDY

I. SUMMARY AND CONCLUSIONS

Summary

1. Construction of the Jefferson and Whitehall Units will provide storage and regulation of river flows for irrigation, power, flood control, and fish and wildlife.

2. The counties affected by the Jefferson and Whitehall Units are Beaverhead, Broadwater, Gallatin, Jefferson, Madison, Lewis and Clark, and Silver Bow. The latter two areas, however, are affected to a lesser extent.

3. The study area is sparsely populated and relatively isolated from large markets. The economic base is agriculture and mining, and to a lesser extent, logging. The total population of the area was 120,000 in 1960 and has been relatively stable over the past two decades.

4. The primary use of surface water within the study area is for irrigation and recreation. Some of the streams serve as raw water supplies for municipal and industrial water users, and some receive sewage effluents and mine drainage. Ground water potential is such that no foreseeable water use in the area would result in overdevelopment of the ground water reservoir.

5. Construction of the Jefferson and Whitehall Units will cause changes in present stream regimes, and in quality of water in some of the streams. The nature of these changes, and their effects on water uses have been given consideration in this study.

Conclusions

1. The study area offers some resource advantages which will enable it to make contributions to certain aspects of the anticipated rise in demand in regional and national markets. Expanded development of the agriculture, mining, and timber resources is forecast.

2. There are sufficient timber resources available in the study area to support a pulp mill. For the purposes of this study it has been assumed that a pulp mill providing adequate waste treatment will locate in the area by 1985. Its daily capacity is forecast as 200 tons in 1985 to 300 tons by 2010.

3. Population of the study area is expected to increase from 120,000 in 1960 to 250,000 by 2060.

4. The development of the Jefferson and Whitehall Irrigation Units will result in a 2.5 percent increase of both dissolved solids and hardness of the Missouri River at Toston. These increases are not considered to have any significant effect on water quality.

5. With or without project development, streamflows are adequate for the assimilation of adequately treated municipal waste waters.

6. For the purpose of maintaining water quality and protection of the fishery resources on the Jefferson River, it is assumed that a pulp mill locating in the Three Forks area will discharge its adequately treated wastes to the Missouri River.

7. At this time, no need is foreseen for inclusion of storage for regulation of streamflow for the purpose of water quality control. Hence, no economic benefits have been assigned to the Jefferson and Whitehall Units.

8. The Jefferson and Whitehall Units are an integral part of the water resources development of the Missouri River Basin. Since this study has been made in advance of any comprehensive study of the Missouri River Basin, the findings, presented in this report, are preliminary and subject to revision upon completion of comprehensive studies for water supply and water quality management in the Missouri River Basin.

II. PROPOSED DEVELOPMENT AND DESCRIPTION OF STUDY AREA

Proposed Project Development (1)

The principal feature in the development of the Jefferson and Whitehall Units is the Reichle Dam and Reservoir on the Big Hole River. This will be a multipurpose structure to store and regulate river flows for irrigation, power, flood control, and fish and wildlife. Reichle Dam will be located about 15 miles upstream from the confluence of the Beaverhead and Big Hole Rivers. The Big Hole River, the largest tributary of the Jefferson River, is the principal source of water for the project. The major facilities proposed for development are:

1. Reichle Dam and Reservoir

   Reichie Reservoir will have a total storage capacity of 600,000 acre-feet with 350,000 acre-feet for irrigation, flood control, fishery, and power. Penstocks will be installed through the dam, but construction of other power facilities will be deferred indefinitely.

2. Whitehall Diversion Dam

   This structure is to be built on the Big Hole River about nine miles downstream from the Reichle Dam. Diversions will be made to the Whitehall Canal.

3. Whitehall Canal

   This canal parallels the Big Hole and Jefferson River and terminates near the town of Whitehall. Water carried in this canal will provide full service water supply for about 7,300 acres and supplemental water supply for about 2,800.

4. Jefferson Dam

   The Jefferson Diversion Dam will be constructed on the Jefferson River about one mile below the confluence of the Big Hole and Beaverhead Rivers. Diversions will be made on the east side of the Jefferson River to the Jefferson Canal.

5. Jefferson Canal

   This canal will provide a full service water supply to about 3,300 acres of land and a supplemental water supply for about 950 acres. At a point about five miles below Jefferson Island the canal will go

through a siphon under the Jefferson River and continue northward to terminate in Milligan Reservoir.

6. Milligan Reservoir

This reservoir will be located on Milligan Creek, a small intermittent tributary of the Jefferson River, and have a total capacity of 42,100 acre-feet -- 7,100 acre-feet will be dead and inactive storage. Milligan Reservoir will provide regulatory storage for most of the Jefferson Unit lands.

7. Townsend Canal

Water from Milligan Reservoir will feed the Townsend Canal which runs northward for about 95 miles and terminates near the Canyon Ferry Dam above Helena. In addition to feeding other canals, the Townsend Canal will provide full service water supply for about 16,300 acres, and a supplemental supply for about 5,400 acres in the Townsend area.

The location of the reservoirs, counties and major municipalities are shown in Figure 1 (preceding back cover).

Description of Study Area

Location (1)

The Three Forks Division, located in southwestern Montana, encompasses all of the area drained by the Missouri River and its tributaries upstream from Canyon Ferry Reservoir, about 15,610 square miles. The area is bounded on the west and south by the Continental Divide, and on the east by the Yellowstone-Missouri Divide. The Missouri River is formed by the confluence of the Jefferson, Madison, and Gallatin Rivers near the town of Three Forks. The Jefferson River, formed by the confluence of the Beaverhead and Big Hole Rivers near the town of Twin Bridges, has a drainage area of about 9,520 square miles compared to 2,520 square miles for the Madison and 1,840 square miles for the Gallatin.

Boundaries

For the purpose of this study the counties of Beaverhead, Broadwater, Gallatin, Jefferson, Lewis and Clark, Madison, and Silver Bow were considered as the counties affected by the project. Although part of Silver Bow County is adjacent to the Big Hole River, the project would have little or no effect on the area. The population and

economic growth of Silver Bow County is primarily centered around Butte, on the west side of the Continental Divide.

Soils (1)

The soils are either benchland soils developed from deposits mantling tertiary sediments, or are alluvial soils developed from reworked tertiary and other materials. Deposits mantling the benches are wind and waterlaid loess or are colluvial fans of gravel and other materials. Due to cool, dry climate, the benchland soils have developed the zonal characteristics of the Brown Soil Group, except that in the 18-inch rainfall belt in the vicinity of Bozeman, shallow black earths have developed.

Drainage (1)

Most of the areas for which irrigation development is planned are elevated benches dissected by natural coulees and draws. These natural channels, separating and bordering most of the irrigable areas, are usually deeply entrenched and will serve as surface drains and outlets for constructed drainage systems.

Extensive areas in the valley bottoms are now affected by high water tables resulting from present poor irrigation practices. The high quality of the water flowing over and through these soils has not caused deterioration except where surface irregularities or heavy soils have permitted long continued evaporation of standing water or of capillary water rising from a shallow water table. Available information about the subsurface strata and flows does not indicate danger of causing increased soil deterioration in the wet lands by increasing the irrigation in higher areas. Plans for new developments provide for protective drains to prevent spread of the high water table to land not now affected.

Salinity and Alkalinity

Generally the high quality water flowing over and through the soil has not permitted salt accumulation, but salt has accumulated where heavy soils, surface irregularities or other conditions have caused evaporation either from standing surface water or from capillary water rising from a water table. Present knowledge of topography and subsurface structure does not indicate that the salty areas will enlarge or that new salty areas will develop after the planned new irrigation is installed.

Topography (1)

The Three Forks Division includes high precipitous mountains and broad, flat valley bottoms. Land classed as irrigable, however, generally has favorable topographic features. Most of the irrigable land have gradients ranging from one-half to two percent. Surface undulations are such that light to medium land leveling will be generally sufficient for irrigation. Elevations range from over 11,000 feet in the mountains west of Dillon to 3,800 feet at Canyon Ferry Reservoir.

Climate (2)

The climate of the Three Forks area varies from semi-arid in the valleys to sub-humid in the mountains. Annual precipitation ranges from less than ten inches near Canyon Ferry Dam to more than thirty inches in the mountains near Yellowstone Park. Most of the precipitation in the higher mountains occurs as snow. Temperatures range from a winter low of -64° to midsummer highs of about 100°. The growing season varies from 130 to 137 days. Prevailing winds are from the west and are usually quite strong in the winter and early spring.

Transportation (2)

Good access to nearly all parts of the area is provided by Federal and State highways. Numerous secondary state and county roads serve local communities. The Chicago, Milwaukee, St. Paul and Pacific Railroad traverses the area from east to west. The Northern Pacific Railway also crosses the area from east to west and has several branch lines connecting larger towns and market centers to the main line. A branch line of the Union Pacific Railroad crosses the area from its extreme southern tip to Butte.

Principal Trade Centers

Helena, Bozeman, and Dillon are the principal trading centers for the area. Butte, located across the Continental Divide, is a trading center utilized primarily by the population centered in the northeastern part of Beaverhead county.

III. THE ECONOMY

An assessment of future water needs necessarily involves an appraisal of the area's future industrial and population growth potential. The growth prospects of an area depend on its competitive advantage in attracting new industries and/or expanding existing ones to supply the ever increasing regional and national demand for goods and services. An analysis and estimate of the future growth pattern in this study are based on a comparison of past trends between the Basin, State of Montana, and the United States on three basic measures; employment, production, and population, modified as appeared warranted in light of anticipated national demand, pattern of regional development, and quantity and quality of local resources.

The study area comprises a seven-county area -- Beaverhead, Broadwater, Gallatin, Jefferson, Lewis and Clark, Madison, and Silver Bow. It is recognized that the area of economic interdependence extends outward, but that project development will influence and be influenced by the more limited area of impact: Beaverhead, Broadwater, Gallatin, Jefferson, and Madison counties.

General Economic Setting

The study area is sparsely populated and relatively isolated from large markets. In 1960 there were 6.4 persons per square mile in the whole of the seven-county area, but an average of only 1.8 persons per square mile outside of the urbanized area of the three largest cities of the study area: Butte, Helena, and Bozeman. This compares to a density of 4.6 for the state of Montana.

In the study area, as is typical of most areas not highly urbanized, extractive industries dominate. The economic base is agriculture and mining and to a lesser extent, logging. Approximately 20 percent of the labor force in 1960 in the study area, as well as in the state of Montana, was employed in these three industries compared to eight percent for the nation. Manufacturing which is geared for the national market is limited largely to primary processing (ores are reduced to ingots or sheets and logs to lumber or veneer); while that which is slated for the local consumer market is minor and confined largely to commodities that characteristically have a comparatively small geographic market area such as certain food and feed products and printing. Employment in service categories, with the exception of State Government offices at Helena and several small colleges, serves primarily the local population.

Industrial Employment and Production Trends

Population and total employment in the study area changed little during the 1940-60 period. However, agriculture and mining have indicated sharp declining trends in employment, while logging, manufacturing, and services have grown. Production in all industries has increased with the exception of mining. Employment trends for each of the major industrial groups are shown in Table I.

Agriculture

Agriculture in the study area is devoted primarily to the production of livestock and livestock products, amounting to about three-fourths of total farm output. Much of the remainder is in small grains and forage crops that serve to support the main enterprise. Total output in 1959 was valued at 44 million dollars.

Farming is one of the most important basic industries in terms of employment. However, with increased use of equipment and scientific discoveries, the number of workers in agriculture declined from 6,900 in 1940 to 5,100 in 1960. Notwithstanding, production continues upward. The local agricultural industry has been in a favorable position compared with the nation. Employment is decreasing at a lesser rate, proportionately more land is being added annually, the rate of production increases is higher, and gross output per worker is measurably greater in the study area.

Mining

Much of the economic activity of the area stems from its mineral wealth. There were 14 kinds of minerals extracted in 1960 valued at 75 million dollars, the most important being copper - 59 million dollars. Mineral resources is the basis upon which a large segment of employment in the study area rests. Its influence, however, is decreasing. The number employed in mining, following the national trend, declined significantly. It dropped from 8,800 in 1940 to 6,500 in 1950 and to 3,700 by 1960, a decrease of 44 percent during the last 10-year period compared to a state and national decline of 27 and 30 percent, respectively. As in agriculture, technological advancements have greatly reduced labor requirements per unit of output. Thus, in spite of a drastic curtailment in employment, monetary value of output remained essentially unchanged from 1951 to 1960. However, much of the mineral wealth is presently marginal and increases in mining must await increased demand and/or improved methods of mining which would make these deposits competitively more favorable.

Table I

Industrial Employment and Location Quotients[1]
1940, 1950, and 1960

Employment Category	1940			1950			1960		
	Number	Percent	L.Q.	Number	Percent	L.Q.	Number	Percent	L.Q.
Agriculture[2]	6,863	13.9	.9	6,471	13.8	1.2	5,111	11.0	1.8
Mining	8,837	17.9	10.5	6,510	13.9	9.3	3,672	7.9	8.8
Manufacturing	2,189	4.4	.2	2,931	6.3	.3	3,287	7.1	.3
Durable Goods	(834)	(1.7)	.2	(1,535)	(3.3)	.3	(1,544)	(3.3)	.2
Furniture, Lumber, Wood Products	190	.4	.2	344	.7	.4	524	1.1	.7
Primary Metals				699	1.5	.8	501	1.1	.6
Fabricated Metals[3]	583	1.2	.2	210	.4	.1	200	.4	.1
Other Durables	61	.1	*	282	.6	.3	319	.7	.3
Nondurable Goods	(1,355)	(2.7)	.3	(1,396)	(3.0)	.3	(1,743)	(3.7)	.3
Food & Kindred Products	698	1.4	.7	759	1.6	.7	796	1.7	.7
Textile Mill Products	4	-	*	19	-	*	7	-	*
Apparel & Other Fabricated Textile Products	36	.1	*	11	-	*	4	-	*
Printing, Publishing, Allied Products	477	1.0	.8	516	1.1	.8	566	1.2	.8
Chemicals & Allied products	51	.1	*	47	.1	*	285	.6	.5
Other Nondurable & NEC	89	.2	*	44	.1	*	85	.2	*
Total Extractive & Manufacturing	17,889	36.3	1.0	15,912	34.0	.9	12,070	25.9	.8
Service	22,578	45.8	1.0	29,024	62.0	1.1	31,744	68.2	1.1
Educational				2,243	4.8	1.4	3,442	7.4	1.5
Public Administration				2,741	5.8	1.4	3,058	6.6	1.4
Military				96	.2	*	106	.2	.1
Other				23,944	51.2	1.1	25,138	54.0	1.1
Unemployment[4]	8,811	17.9	1.2	1,846	4.0	.9	2,761	5.9	1.2
Labor Force	49,278			46,782			46,575		
Population	115,959			114,469			120,011		

[1] The location quotient as used here is computed by dividing the quantity (number of labor force in a given industry in the study area divided by the total labor force of the study area) by the quantity (number of labor force in the same industry in the nation divided by the labor force of the nation). It is thus an index which indicates if the study area has more or less than its "proportionate" share of the indicated industry. A location quotient of less than unity indicates that that particular industry employs a smaller proportion of its total labor force in the study area than it does in the nation as a whole. A location quotient greater than unity, say 2.0, for example, indicates that that industry in the study area has twice its proportion of the labor force relative to the proportion that industry has of the nation's labor force. No location quotient was computed for industries employing less than 100 workers.

[2] Includes a small (approximately one (1) percent of total in category) number in certain forestry and fisheries categories.

[3] Includes machinery, electrical equipment, and all transportation equipment.

[4] In 1940 includes those employed part time or temporarily by WPA, NYA, etc.

*No location quotient was computed for industries employing less than 100 workers.

Forestry

Among the three extractive industries, forestry has exerted the least economic impact. Total employment in logging, lumbering, and manufacturing of wood products in 1960 was 500, about one-tenth that of either farming or mining. Unlike the latter two industries, however, employment and production in forest industries have been increasing.

There are 4 million acres of commercial forest lands in the study area supporting a stand of approximately 4.3 billion cubic feet. Conifers make up 99 percent of the volume. The two most important species are lodgepole pine and Douglas fir, which together comprise 83 percent of the commercial timber.

The timber stand is largely marginal. Much of it is small in diameter: 60 percent of the cubic-foot volume is pole size (5.0 inches to 10.9 inches), while only 5 percent is larger than 20 inches in diameter. Inadequate access roads, a small local market, and transportation disadvantages to larger national markets, have handicapped development.

The competitive disadvantage of the timber resources is manifest not only by the fact that there is a net importation of lumber and wood products, but also that only a small part of the available stand is used. A lessening of the economic disadvantage of the timber stand and wood product production is implied by the increase in the location quotient from 0.2 in 1940 to 0.7 in 1960.

Manufacturing

The number employed in manufacturing in 1960 totaled less than 3,300, which is only 7 percent of the total labor force, compared to 9 percent for the state and 25 percent for the nation. In none of the major manufacturing categories does the study area have its "share" as measured by the location quotient. The two largest manufacturing categories in terms of the number employed, (1) food and kindred products, and (2) printing, publishing, and allied products, are population oriented. The next two categories of importance, (1) lumber and wood products, and (2) primary metals, are essentially engaged only in primary processing -- very little fabrication is carried to the finished consumer product stage.

Of the 149 manufacturing plants reported in 1958, 115 had less than 20 employees and only 6 had more than 100. None employed more than 250. Between 1940 and 1960 employment advanced in all of the manufacturing groups that employed in excess of 100 workers, resulting in a total increase in manufacturing employment of 50 percent.

Output during this time increased approximately 65 percent. Manufacturing employment in Montana increased 66 percent during this period, while output increased 113 percent. National trends were 70 percent and 142 percent, respectively. The low level of manufacturing development and its slow rate of growth in the area can be explained largely by the lack of local markets and remoteness and hence its competitive disadvantage in the large national markets.

Service Industries

The administration of government services and facilities, the provision of business and professional services, the sale and distribution of goods, and the furnishing of financial and insurance services and other similar conveniences constitute a large segment of the economic activity of the area. Employment in service industries accounted for about two-thirds of total employment, or nearly 32,000, in the seven-county area in 1960. Total employment in the service industries is a larger part of the labor force in the study area than it is for the state or nation.

Population Trends

Total population has fluctuated between 111,000 and 120,000 for the 50-year period, 1910-60. Urban areas and towns have increased in population while rural areas have decreased. This was caused by a diminution of labor requirements in agriculture, consolidation of farms, desire of farmers to live in towns, and more efficient transportation. Likewise, suburbs have become part of the urban complex.

Economic Outlook: Employment and Population

An increase in the national population to an estimated 380 million in the year 2010 and 580 million by 2060, coupled with a national policy designed to encourage increased per capita consumption, should result in a significant increase in demand for goods and services. The study area offers some resource advantages which will enable it to make contributions to certain aspects of the anticipated rise in demand for regional and national markets. Employment forecasts by major industrial categories and projected population are shown in Table 2.

TABLE 2

Industrial Employment and Population, 1940, 1950, 1960, and Forecasts for 2010 and 2060

Employment Category	1940		1950		1960		2010		2060	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Agriculture	6,863	13.9	6,471	13.8	5,111	11.0	3,100	4.9	2,000	2.5
Mining	8,837	17.9	6,510	13.9	3,672	7.9	4,000	6.2	5,000	6.2
Manufacturing	2,189	4.5	2,931	6.3	3,287	7.0	7,000	10.9	10,000	12.5
Durable	834	1.7	1,535	3.3	1,544	3.3	4,000	6.2	6,000	7.5
Nondurable	1,355	2.8	1,396	3.0	1,743	3.7	3,000	4.7	4,000	5.0
Total Extractive and Manufacturing	17,889	36.3	15,912	34.0	12,070	25.9	14,100	22.0	17,000	21.2
Service	22,578	45.8	29,024	62.0	31,744	68.2	47,300	73.9	60,000	75.0
Unemployment	8,811	17.9	1,846	4.0	2,761	5.9	2,600	4.1	3,000	3.8
Total Labor Force	49,278	100.0	46,782	100.0	46,575	100.0	64,000	100.0	80,000	100.0
Population	115,959		114,469		120,011		180,000		250,000	
Ratio Labor Force to Population		.425		.409		.388		.356		.320

Agricultural production will continue to increase, aided in part by an expansion in irrigation. However, farm employment is expected to decrease further in response to improvements in agricultural science and technology. It is estimated that the number of farm workers will decrease from 5,100 in 1960 to 2,000 in 2060.

Mineral resources in the study area abound, but much of the known deposits are marginal under present market conditions. However, given a favorable demand situation, increased extraction of of minerals in the study area in the future is expected. Reserves of copper could assure production for many years to come. Deposits of magnetite (iron) ore averaging 30 percent is estimated at 200 million tons. Deposits of bituminous coal are available. Mining of thorium could increase significantly if technological breakthrough replaces uranium with thorium for nuclear power. Growing demand for fertilizer should reflect increased phosphate mining. The extraction of clay, limestone, sand, and gravel is expected to increase, but only to meet the needs of the local market. Total mineral production is expected to double with little change in employment by 2010. A greater increase is expected during the succeeding 50-year period.

There are significant timber resources available. One million cords of green timber is now annually available for curing on a sustained yield basis. This can be doubled by better forest management. Approximately one-third of the timber stand is most economically suited for lumber, poles, and veneer, and the remainder for pulpwood and less valuable uses.

There is expected to be a gradual increase in the need for the area's timber resources. However, maximum use of these resources must await more favorable market conditions. A steady rise in production of lumber, veneer, and poles is foreseen followed by pulp production by about the year 1985, with a daily capacity of 200 to 300 tons. The site most often discussed by promoters has been in the Three Forks area where sufficient pulpwood and mill residue are available within a 60-mile radius. The establishment of one or two medium size composition board manufacturing plants likewise seems probable. Neither the species of trees nor the probable size of the future local consumer market (coupled with freight handicaps to national market) holds much promise for furniture or other wood products manufacturing. The combined production of lumber, pulp and composition board is expected to use about half of the production capacity of the forests in the study area.

Additional resource-oriented manufacturing possibilities include an iron ore concentrating plant at Dillon of approximately

2,000 tons daily capacity and a steel mill in the Anaconda-Butte area, manufacturing primarily structural steel and reinforcing rods. Increased manufacturing in some food categories, notably beef processing, is likely. Canning of specialty crops is not encouraging because the climate imposes limitations.

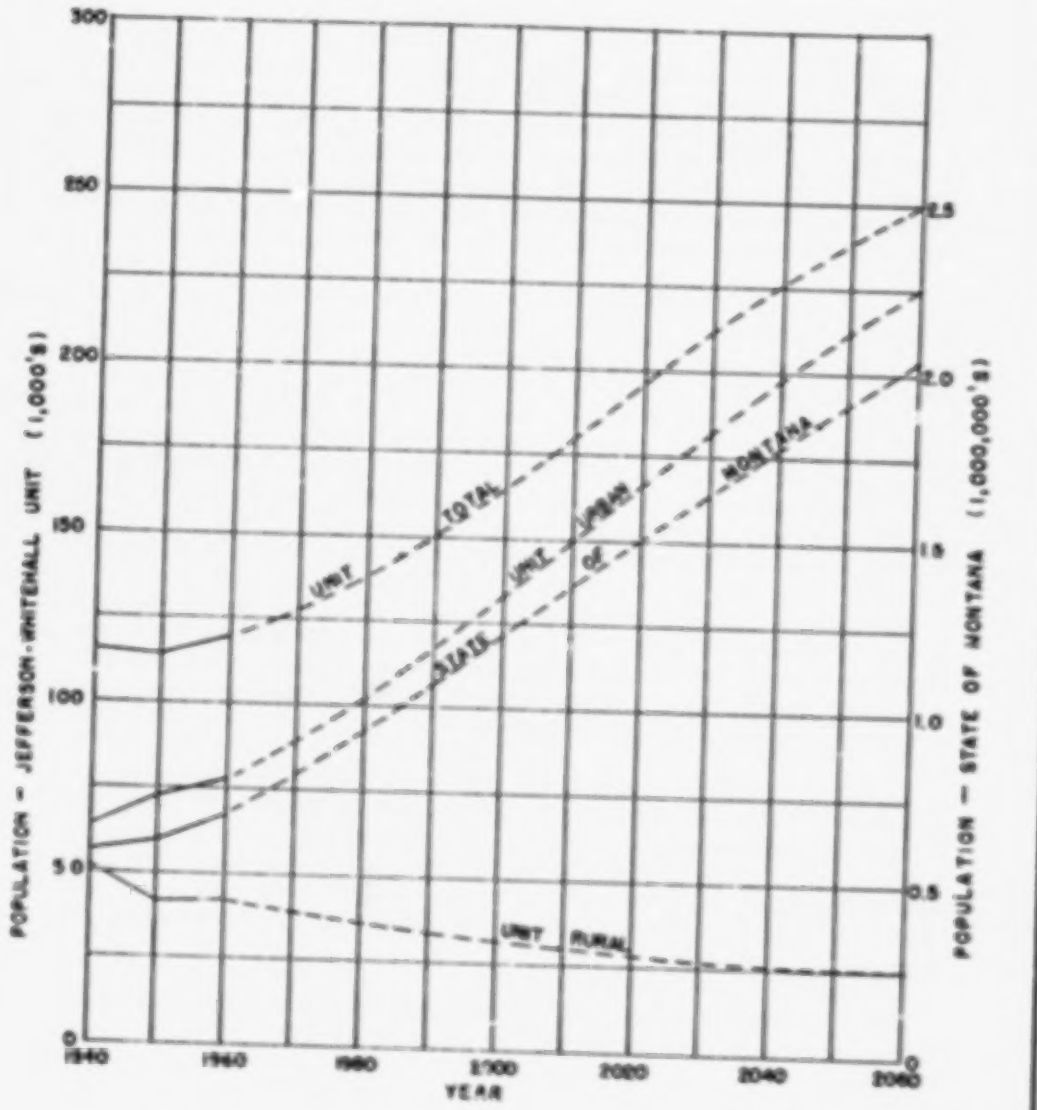
Although the trend toward diversification and consumer-oriented manufacturing generally follows the expansion of a primary manufacturing base, lack of local markets and long distances to national markets will retard this development in the study area. Accordingly, manufacturing categories such as apparel, fabricated metals and machinery hold little promise for increased production.

Total employment engaged in manufacturing is expected to increase from 3,300 in 1960 to 10,000 by 2060. Nearly an even division is anticipated between the manufacturing of durable and nondurable goods.

In addition to basic employment in the extractive and manufacturing industries there are a large number of employees engaged in construction, transportation, communications, utilities and sanitary service, distribution, finance, public administration, and other services. Employment in finance, public administration, and distribution will likely experience the fastest rate of growth. A relatively greater increase in number of service workers compared to basic workers is expected in response to shifts in pattern of production and distribution, increases in real income and changes in cultural norms. Employment in this category is expected to increase from 31,700 or 68 percent of the labor force in 1960, to 60,000 or 75 percent of the labor force by 2060.

Total anticipated employment was estimated on the basis of the preceeding analysis. To determine the size of the labor force, an unemployment rate of 4 percent was assumed. Total population was estimated by applying the historic trend of the ratio of labor force to population. On this basis total population is expected to increase from 120,000 in 1960 to 250,000 by 2060 (Figure 2).

The expected industrial expansion and population growth in the study area during the projection period will result in an increase in the waste loadings discharged to the streams. The effects of the expected economic change on stream quality are recognized and evaluated in Sections V and VI of this report.



WATER RESOURCES STUDY THREE FORKS DIVISION, MONTANA JEFFERSON AND WHITEHALL UNIT
POPULATION
DEPT. OF HEALTH, EDUCATION, & WELFARE PUBLIC HEALTH SERVICE REGION VIII DENVER, COLO.

17A

FIGURE 2

IV. WATER SUPPLY

Ground Water

Geologic and ground water investigations have been made by the U. S. Geological Survey (USGS) for the Gallatin Valley and Townsend Valley areas. (3)(4) Subsequent to these reports several large production wells have been drilled which confirms USGS findings that large ground water developments are possible.

In the Townsend Valley area two principal sources of ground water are available. Along the major stream valley bottoms are unconsolidated sand and gravel aquifers, ranging up to 60 or 70 feet in thickness. USGS reports that wells penetrating this aquifer are capable of a sustained yield of 1,000 gallons per minute (gpm) of good quality water. Much of the lower land underlain by this aquifer is plagued with a high water table and irrigation wells are not needed in these areas. Several wells yielding up to 1,500 gpm are located south of the town of Townsend, along lower Crow Creek and on the east side of the Missouri River.

USGS reports that a large ground water potential exists in the Gallatin Valley. Wells capable of yielding up to 2,500 gpm are reported to have been completed in this area. It has been estimated by the USGS that at least 300,000 acre-feet of ground water can be developed in this basin.

The lower courses of the Madison and Jefferson Valleys are underlain by 60 to 80 feet of unconsolidated sand and gravel. Several large capacity wells have been drilled in these areas, however, the potential yield has not been determined. The ground water potential in Madison Valley above Ennis, Montana, is not known, but it has been reported by USGS that large capacity wells have been developed.

Several large capacity wells have been reported in the Jefferson-Beaverhead drainage area. Although little hydrologic work has been done in this area, the USGS reports that the ground water potential appears to be great. Irrigation wells capable of producing 2,500 gpm have been drilled in the Blacktail Deer Creek Valley above Dillon.

In all cases the USGS reports that ground water development will yield water of good to excellent quality. Recharge to the ground water reservoirs is from precipitation, infiltration from streams, and from water spread for irrigation.

Surface Water

The principal source of irrigation water supply will be the Big Hole River as regulated by the proposed Reichle Reservoir. Regulatory storage for the Jefferson unit will be provided by the Milligan Reservoir. Runoff from Pipestone and Whitehall Creeks will supply some of the water for the Whitehall Unit. The location, period of record, maximum, minimum and average flows for the USGS stream gaging stations pertinent to the determination of available streamflows appear in Table 3.

Quality

Mineral

The primary use of surface waters within the study area is for irrigation and recreation. Some of the streams serve as raw water supplies for municipal and industrial water users, and some receive sewage effluents and mine drainage. In general, the quality of surface waters is acceptable for existing uses. Investigations concerned with the chemical quality of surface waters in the Three Forks area were initiated by a cooperative study between the Montana State Board of Health and the Montana State Fish and Game Department in October 1959. Data from the first two years of this study (5) are summarized in Table 4 for the following sampling stations:

1. Big Hole River at Twin Bridges -- northeast of Twin Bridges near the confluence of Big Hole and Beaverhead Rivers.

2. Beaverhead River at Twin Bridges -- at bridge crossing the river in the city of Twin Bridges.

3. Jefferson River above Three Forks -- at bridge near junction of Highways 90 and 12 north of the city of Three Forks.

4. Madison River near Three Forks -- first bridge crossing on Highway 10 east of the city of Three Forks.

5. Gallatin River at Trident -- 100 yards above bridge crossing at Missouri Headwaters State Park.

6. Missouri River at Trident -- one mile above the Ideal Cement Company plant north of Trident.

7. Missouri River at Toston -- below bridge at Toston.

In addition to the above stations, USGS water quality data of the Big Hole River at Melrose and the Gallatin River at Logan are shown in Table 4.

TABLE 3
Streamflow Data (USGS)

River Station	Period of Record	Flows of Record			
		Maximum (cfs)	Minimum (cfs)	Average (cfs)	(acre-feet/year)
Beaverhead River at Barratts 1/	1907-62	3,720	69	402	291,000
Beaverhead River at Blaine 2/	1935-62 1940-43	3,130	7	388	280,900
Ruby River near Twin Bridges 3/	1946-62	1,500	1.8	189	136,800
Big Hole River near Melrose 4/	1923-62 1940-43	14,100	49	1,091	789,900
Jefferson River near Twin Bridges 5/	1957-62 1929-32	13,200	155	1,846	1,336,000
Boulder River near Boulder 6/	1934-62 1896-1906 1938-62	2,620 21,000	0 134	110 2,086	79,640 1,510,000
Jefferson River at Sappington 7/	1938-62 1889-94 1930-62	7,750 8,060	210 117	1,602 761	1,160,000 550,900
Madison River below Ennis Lake 8/	1893-1905 1928-62	9,840	130	957	692,800
Gallatin River near Gallatin Gateway 9/	1941-62	32,000	562	5,127	3,712,000
Gallatin River at Logan 10/					
Missouri River at Toston 11/					

1/ 8¼ miles southwest of Dillon, one-mile upstream from Barratts. Diversions for irrigation of about 90,000 acres above station. Some regulation by Lima Reservoir.

2/ 14½ miles northeast of Dillon. Diversions for irrigation of about 115,000 acres above station. Some regulation by Lima Reservoir.

3/ 1½ miles above mouth, 2½ miles south of Twin Bridges. Diversions above station for irrigation of about 28,500 acres. Some regulation by Ruby Reservoir.

4/ Seven miles south of Melrose. Diversions for irrigation of about 136,000 acres above station.

5/ Four miles below confluence of Beaverhead and Big Hole Rivers. Diversions for irrigation of about 500,000 acres above station. Some regulation by Ruby and Lima Reservoirs.

6/ Two miles southeast of Boulder. Diversions for irrigation of about 3,500 acres above station.

7/ One mile northeast of Sappington. Diversions for irrigation of about 345,000 acres above station. Some regulation by Lima and Ruby Reservoirs.

8/ 1½ miles below Ennis Lake, six miles northeast of McAllister. Diversions for irrigation of about 23,000 acres above station. Flow regulated by Hebgen and Ennis Lake.

9/ 7½ miles south of Gallatin Gateway. Diversions for irrigation of about 1,400 acres above station.

10/ Six miles upstream from mouth, 1/2 mile west of Logan. Diversions for irrigation of about 110,000 acres above station.

11/ Two miles southeast of Toston. Some regulation by six reservoirs on tributaries. Diversion for irrigation of about 535,000 acres above station.

TABLE 4
Chemical Quality of Surface Waters 1/
(Milligrams per liter)

	Big Hole River		Beaverhead River at	Jefferson River above	Madison River near	Gallatin River		Missouri River	
	Melrose 2/ 8/56-9/57	Twin Bridges 10/59-9/61	Twin Bridges 10/59-9/61	Three Forks 10/59-9/61	Three Forks 10/59-9/61	at Logan 2/ 8/56-9/57	at Trident 10/59-9/61	at Trident 10/59-9/60	at Toston 10/60-9/61
Dissolved Solids	162	180	410	333	222	268	274	239	265
	64	67	228	94	137	124	91	120	120
	88	84	354	198	4/	201	168	194	202
Hardness	122	240	430	350	155	196	300	255	230
	29	36	240	100	88	92	116	146	108
	50	76	341	191	4/	155	192	203	187
Calcium	35	42	101	69	34	54	69	58	55
	9	14	45	25	22	27	32	32	27
	15	19	75	44	4/	42	44	45	42
Magnesium	8.4	33	54	44	23	28	38	31	33
	0.4	0	13	10	8	12	10	16	14
	3.0	8	37	21	4/	12	18	21	21
Bicarbonates	148	159	293	244	165	228	244	226	226
	36	61	214	98	122	104	122	140	116
	64	77	267	161	4/	172	172	192	171
Sulfates	20	55	280	107	66	42	140	135	62
	4	12	99	20	16	13	25	4	19
	9	21	134	67	4/	27	38	54	42
Chlorides	3	19	22	16	25	4.5	9		17
	0	0	12	2	13	0	1		5
	0.5	2	16	7	4/	2.1	3		12
		3/	3/	3/	3/		3/	3/	

1/ Montana State Board of Health unless otherwise shown -- Maximum, minimum and weighted average
2/ USGS - WSP 1521
3/ 10/60-9/61 only
4/ Weighted average not determined -- streamflow unknown

Sanitary

Based upon data obtained from the Montana State Board of Health, the dissolved oxygen (DO) content in the major streams of the area ranges from 7 milligrams per liter (mg/l) in the Missouri River near Townsend to 12.6 mg/l in the Beaverhead River below Dillon. As the saturation of dissolved oxygen varies with water temperature and barometric pressure, the preceding concentrations of DO represent 86 and 164 percent saturation, respectively.

State Standards

The Missouri River and tributaries in the project area were classified by the Montana Water Pollution Council on May 2, 1961, and approved by the State Board of Health on May 27, 1961. Classification of the streams is not intended to restrict the use of a water taken from a stream by a person, municipality or corporation, but does place restrictions on the wastes that can be returned to the stream to insure classification standards are met in accordance with the streams' most beneficial uses. (6)

Stream classification adopted by the Montana State Board of Health for the streams in the project area are shown in Appendix "A".

Uses

The Missouri River and tributaries in the study area are utilized for municipal and industrial purposes, irrigation, propagation of fish and aquatic life, recreation, and assimilation of waste effluents. Six municipalities depend wholly, or in part, on surface water and 13 utilize wells and springs to provide the required water demand. In rural areas wells and springs are utilized for domestic purposes.

Municipal water usage includes residential, public, commercial and industrial requirements which are served by an organized municipal water system. Quantitative data on separate industrial water requirements or supplies are not available at this time. Table 5 presents a tabular summary of municipal water supplies -- estimated population served, source, treatment and usage data.

TABLE 5
Municipal Water Supplies [1]

Location	Population Served	Source	Treatment	Usage (mgd) [2]
Basin	260	Basin Creek + 2 Auxiliary Wells	Sedimentation & Disinfection	--
Belgrade	1100	3 Wells	None	0.70 (635 gpcd)
Boulder	500	3 Wells	None	0.36 (720 gpcd)
State Training School	910	3 Wells	None	--
Bozeman	13,361	Bozeman & Lyman Creeks	Sedimentation, Fluoridation & Disinfection	4.45 (335 gpcd)
Canyon Ferry	65	2 Wells + Missouri River Auxiliary	Disinfection	0.016 (250 gpcd)
Dillon	4,000	2 Wells + Rattlesnake Creek	Sedimentation Aeration Disinfection	0.735 (185 gpcd)
East Helena	1,448	2 Wells + McClellan Creek	None	0.5 (345 gpcd)
Helena	25,000	4 Wells + Springs + Ten Mile Creek + Missouri River Auxiliary	Disinfection Coagulation Sedimentation, Filtration, Disinfection of Missouri	4.5 (180 gpcd)
Lima	500	Springs	Disinfection	--
Manhattan	900	Springs + Auxiliary Well	Disinfection	--
Sheridan	600	Springs + Indian Creek	Disinfection	--
Three Forks	1,200	4 Wells	None	--
Townsend	1,600	2 Wells	Disinfection	0.50 (310 gpcd)
Trident	100	2 Wells	None	0.209 (2090 gpcd)
Twin Bridges	510	Well + 1 Auxiliary Well	None	0.250 (490 gpcd)
State School	230	2 Wells	None	0.025 (110 gpcd)
Virginia City	200	Springs	None	--
Whitehall	900	3 Wells	None	--

1/ Data from Montana State Board of Health
2/ Million gallons per day, figure in parenthesis represents computed gallons per capita per day (gpcd)

Fish and Aquatic Life

The characteristics of water that serve best as criteria of its suitability for fish life include oxygen content, pH, ionizable salt concentrations and free carbon dioxide, ammonia and suspended solids concentrations. In general, waters favorable for a good fish fauna require -- [8]

1. Dissolved oxygen not less than 5 mg/l.

2. pH ranging from 6.7 to 8.6.

3. Specific conductances at 25°C ranging from 150 to 500 micromhos with a maximum of 1,000 to 2,000 micromhos permissible in western alkaline areas.

4. Free carbon dioxide, not over 3 cc per liter.

5. Ammonia, not over 1.5 mg/l.

The Montana State Fish and Game Department has advanced the following criteria for water quality requirements in addition to those mentioned above --

1. Concentration of copper not to exceed 0.3 mg/l. If large scale mining of copper becomes a reality, a pollutional problem may be experienced

2. Concentration of zinc not to exceed 1.0 mg/l.

3. Temperature of water not to exceed 25°C.

Future Municipal and Industrial Water Requirements

The Public Health Service was not requested to make a specific study of municipal and/or industrial water supply requirements. However, economic projections and population growth for years 1985, 2010, and 2060 have been made to assist in determination of the volume of wastes that may reach the surface waters in the study area. The present average daily water consumption per capita for all municipal water systems was determined to be 255 gallons.

Future per capita water consumption was computed to be 295 gallons per day. This was determined on the basis that per capita use will increase by about one-tenth the percentage increase in population.[7] Separate industrial water requirements were determined where economic projections indicate potential industries requiring large volumes of water, such as pulp mills.

V. MINIMUM STREAMFLOW REQUIREMENTS

Under provisions of the Federal Water Pollution Control Act, 84-660, as amended by Public Law 87-88, in the survey or planning of a reservoir by any Federal Agency, consideration must be given to the inclusion of storage for regulation of streamflow for the purpose of water quality control. It is expressly stated that any such storage and water releases shall not be provided as a substitute for adequate treatment or other method of controlling wastes at their source.

Discharge of wastes, even when treated to the maximum economically feasible and practical limit, will cause an unsatisfactory quality condition in receiving waters whose waste assimilation capacity is exceeded. This condition generally occurs during periods of low streamflow and may be avoided by the addition of water to maintain flow at a higher level. It is essential that recognition be given to the need for flows which must prevail in receiving streams if the quality of their waters is to be maintained at acceptable levels.

Sources of Pollution

Table 6 shows existing wastewater discharges to the Missouri River and tributaries in the project area.

Stream Quality Maintenance

The following criteria and/or conditions were used in determination of water quality control requirements:

1. The organic loading of untreated municipal waste waters would be 0.25 lb. of biochemical oxygen demand (BOD) per person per day. The effect of organic loading from minor industrial development was included in this value.

2. Waste treatment facilities will be provided to remove 85 percent of the BOD present in municipal and industrial waste waters. Treatment will also be provided to reduce the concentration of toxic substances present in industrial waste waters to such a level so that the waste waters can be safely discharged to the receiving stream.

TABLE 6
Sources of Pollution

Community or Industry	Sewered Population	Treatment Provided	Population Equivalent	Discharged to
Townsend [1]	1,500	Lagoon	450	Missouri River
Trident [1]	200	Septic Tank	170	Missouri River
Manhattan [2]	850	Lagoon	250	Gallatin River
Belgrade [2]	710	Septic Tank	0	Gravel Beds
Bozeman [2]	16,000	Primary	11,000	East Gallatin River
Bozeman Pea Cannery [2]	16,600	Lagoons	0	Land Disposal
Vollmar Slaughterhouse [2]	Undetermined	Blood and Paunch Manure Removal only	Undetermined	East Gallatin River
Boulder [3]	700	Lagoon	100	Boulder River to Jefferson River
Three Forks [3]	1,100	Lagoon	330	Jefferson River
Whitehall [3]	800	Lagoon	100	Whitetail Creek to Jefferson River
Twin Bridges [3]	250	Lagoon	250	Beaverhead River
State Orphans Home	150	Lagoon	50	Beaverhead River
Sheridan [3]	500	Lagoon	100	Mill Creek to Ruby River to Beaverhead
Dillon [3]	4,000	Lagoon	800	Beaverhead River

1/ Department of Health, Education, and Welfare, Public Health Service Summary Report on Quality of Interstate Waters, Missouri River (Montana, North Dakota, South Dakota), Region VI, Division of Water Supply and Pollution Control, Kansas City, Missouri, 1962

2/ DHEW, PHS, Summary Report on Quality of Interstate Waters - Gallatin River (Wyoming-Montana), Region VIII, WSPC, Denver, Colorado, 1962

3/ DHEW, PHS, Inventory of Municipal and Industrial Waste Facilities, 1960 (unpublished), WSPC, Washington, D. C.

3. Storage and/or regulated releases of industrial wastes will be utilized to accomplish optimum assimilation capacity of the receiving stream.

4. The effluent from waste treatment facilities will be uniformly mixed in the receiving streams.

5. The dissolved oxygen (DO) content in the surface waters will not be depleted below 5 mg/l during assimilation of waste loads.

6. Stream self-purification coefficients were chosen by analogy and judgment.

7. A 1:1 salt balance will be maintained in irrigated areas.

8. Chemical and physical characteristics of surface waters after treatment will not exceed limits as described in the Public Health Service Drinking Water Standards in areas of municipal water needs.

9. Water quality criteria established or recommended by the Montana State Fish and Game Department will not be exceeded.

Streamflow Requirements

The above were used in determining the needed streamflow to maintain water quality. The need for streamflow regulation was considered under the following three classifications: assimilation of municipal waste waters, assimilation of industrial waste waters, and maintaining or improving the mineral quality of surface waters.

Municipal Waste Waters

The municipalities on the Jefferson River and its tributaries were considered separately from the municipalities located on the Madison River, Gallatin River, and their tributaries. Based on the anticipated 2000 population a minimum flow of 44 cfs in the Jefferson River, from Twin Bridges to the confluence with the Missouri River, will be needed to assimilate the treated waste waters from municipalities located on the Jefferson River and its tributaries. The minimum historic flow of the Jefferson River at Sappington is 134 cfs. The historic minimum flows of the Madison and Gallatin Rivers, 210 cfs and 130 cfs, respectively, were determined sufficient to assimilate the anticipated treated waste waters from municipalities located along these streams. The relatively small population, less

than 5,000 persons, along the Missouri River from Three Forks to Canyon Ferry Reservoir should not add any significant wasteload to the Missouri River. The historic minimum flow of the Missouri River at Toston is 562 cfs, with the flow being greater than 1,000 cfs almost 100 percent of the time. Based on the historic minimum streamflows and considering only the anticipated BOD loadings from municipalities in the area, no need is foreseen for storage of water for purposes of streamflow regulation to maintain water quality as provided for under provisions of the Federal Water Pollution Control Act (P.L. 84-660, as amended by 87-88). This assumes no further development as to water use in the future than is projected by this report. If streamflows should be further reduced, then a re-evaluation of the need for water quality control would be necessary.

Industrial Waste Waters

The effect of wastes from minor industrial development was included with municipal waste waters. Industrial development in the study area is expected to be limited in nature. From a water quality viewpoint the only proposed industrial development of interest is a pulp mill in the Three Forks area. The economic analysis shows that the resource base is available to support a pulp mill having a daily capacity of 200 to 300 tons. The disposal of pulp mill wastes has caused water quality problems in many parts of the United States. Some of the more common problems associated with pulp mill wastes are -- color, odor, unsightly floating matter, deposits of suspended matter, potential toxicity to aquatic life, and high BOD loading. The potential toxicity to aquatic life and high BOD loadings would be extremely important in this area since the nearby streams provide some of the best fresh water fishing in the United States. The Montana State Board of Health has found that the toxicity of wastes from an unbleached kraft mill located in Montana is more of a problem than high BOD loadings. After nine months retention in stabilization ponds the waste had a 96-hour median tolerance limit (TL_m^{96}) of 2.6 percent and the BOD of this waste was 146 mg/l. This median tolerance limit designates the concentration of a waste that will kill 50 percent of test organisms with a 96 hour exposure. However, it is felt that this toxicity can be reduced about 85 percent by appropriate treatment.

A potential pulp mill in this area would, therefore, require very stringent measures to prevent a detrimental effect on water quality as a result of waste discharges. Some important measures would include the following:

1. Efficient pulp mill operation and chemical recovery from process water

2. Efficient secondary treatment, and possibly tertiary treatment of the wastes.

3. Possible additional treatment to remove toxic substances.

4. Possible lagooning or storage of the wastes to allow discharging to streams only during periods of high flow.

5. Close cooperation and consultation with the Montana State Board of Health.

For the purposes of this study, it has been assumed that a pulp mill using the unbleached kraft process will be located in this area by 1985. Mill capacity of 200 tons per day is assumed as of 1985, and ultimate capacity of 300 tons per day by 2010. Any other conditions than those stated above would require a new analysis.

Even after efficient waste treatment, adequate streamflows are necessary to assimilate pulp mill wastes. In determining streamflows needed due to toxicity it was assumed that the toxicity of the waste would be reduced from a TL_m^{96} of 2.6 percent to a TL_m^{96} of 17.3 percent, or an 85 percent reduction in the toxicity. It was assumed that the waste flow would be 5 cfs and 7.5 cfs from 200 and 300 tons per day pulp mills, respectively. This is in the lower range of flows reported[18] for unbleached kraft pulp mills and should be obtainable by a modern, efficiently run pulp mill. Using an application factor of 30, recommended by the Montana State Board of Health, a streamflow of 720 cfs would be necessary for the assimilation of toxic substances present in the adequately treated wastes from a pulp mill having a daily capacity of 200 tons, while 1070 cfs would be needed for a mill capacity of 300 tons per day. The streamflows needed to assimilate the BOD loading of the treated wastes are computed to be 220 and 330 cfs, respectively, for the same mill capacities. Considering the additional BOD loadings from municipal and other industrial waste waters, the streamflows needed for assimilation of toxicity exceed those needed for BOD assimilation.

Studies made by the Bureau of Reclamation show that the historic streamflow (1926-1961) of the Jefferson River at Sappington has an average flow of about 1800 cfs. However, there were 69 months (15 percent of the time) when the average monthly flow was less than 720 cfs and 144 months (33 percent) when the average flow was less than 1070 cfs. In addition, the average annual flow was less than 720 cfs one year and less than 1070 cfs four years during this period. The Bureau of Reclamation's project operations study indicate that under project conditions the future flow of the Jefferson River at Sappington would be less than 720 cfs about ten percent of the time and less than 1070 cfs 50 percent of the time. The study also indicates that the average annual flow would be less than 720 cfs two years and less than 1070 cfs ten years in a 36 year period.

Under historic conditions an average of 33,000 acre-feet of water would be needed annually for streamflow regulation to maintain a minimum flow of 720 cfs in the Jefferson River at Sappington. Similarly, an average of 94,000 acre-feet would be needed to maintain minimum flow of 1070 cfs. Under project conditions an average of 7,800 acre-feet would be needed to maintain a minimum flow of 720 cfs, while 93,000 acre-feet annually would be needed for a minimum flow of 1070 cfs.

The USGS streamflow records show that from 1951 to 1962 there were 16 months (11 percent) when the monthly average flow of the Madison River below Ennis Lake was less than 1070 cfs. The recorded minimum daily flow is 210 cfs. For the same period the monthly average flows of the Gallatin River at Logan were less than 720 cfs a total of 55 months (38 percent) and less than 1070 cfs, 116 months (90 percent). The recorded minimum flow is 130 cfs. As the proposed Jefferson and Whitehall Units will have no effect on the flows of the Madison and Gallatin Rivers, streamflow regulation of these two rivers was not considered.

The mean daily flow of the Missouri River at Toston fell below 1070 cfs a total of 35 days (0.5 percent) from 1941 to 1962 according to the USGS streamflow records. During this period the mean daily flow did not fall below 720 cfs, with the instantaneous flow once dropping to the recorded low of 563 cfs. Under project conditions there would be a reduction in the number of days in which the flow would fall below 1070 cfs. No need is seen for regulating the flow of the Missouri River at Toston to maintain a minimum flow of 1070 cfs since this flow is essentially met 100 percent of the time.

The Jefferson River, along with the Madison, Gallatin, Beaverhead, and Big Hole Rivers, is considered one of the better fishing streams in the State of Montana. With the increasing use of outdoor recreational areas, it is highly desirable to maintain the water quality of these streams. The location of a pulp mill on any of these streams is undesirable because of the possible adverse effect that the treated pulp mill wastes may have on water quality. This would be especially true during those periods when streamflow fell below the flows required for the assimilation of the pulp mill wastes. With or without project development there would be times when these required flows could not be met. The required streamflows would be met essentially 100 percent of the time in the Missouri River at Toston. In addition, the higher flows of the Missouri River would reduce the possibility of the wastes having any long range adverse effect on the aquatic life of the receiving stream. For the purposes of maintaining water quality it would be logical and desirable for a pulp mill locating in the Three Forks area to discharge its treated wastes to the Missouri River.

Mineral Quality

The effects of the present upstream development are reflected in the water quality conditions of the Missouri River at Toston, immediately upstream from the Canyon Ferry Reservoir. The present weighted average concentrations of dissolved solids and hardness at this point are 216 mg/. and 142 mg/l, respectively.

The development of the Jefferson and Whitehall Units will result in an increase in the weighted average annual concentration of dissolved solids and hardness of the Missouri River at Toston. This increase in concentration will be due primarily to a reduction of flow caused by evapo-transpiration losses in the Jefferson and Whitehall Units and evaporation losses from the proposed reservoir.

Under project operation computations indicate that both the concentration of dissolved solids and hardness will increase about 2.5 percent. The average annual values expected are 222 mg/l for dissolved solids and 146 mg/l for hardness. Under project operation the annual salt load carried in the Jefferson River at Twin Bridges and at Three Forks will be less than without the project because of project diversions of streamflow above these areas with return flows entering the Missouri River below Three Forks. However, no significant change is anticipated in the annual salt load at Toston.

A summary of the computed effects of the project on salt concentrations at select stations is shown in Table 7.

TABLE 7

Concentration of Total Dissolved Solids and Annual Salt Load

Location	Total Dissolved Solids: Weighted Annual Mean (mg/l)	Total Dissolved Solids: Tons per Acre-foot	Annual: Flow (Acre-feet)	Annual: Salt Load (Tons)
	Present		Present	
Big Hole River at Reichle Reservoir Site	93	0.13	845,000	107,000
Jefferson River at Twin Bridges, Montana	217	0.30	1,219,000	359,000
Jefferson River above Three Forks, Montana	211	0.29	1,306,000	374,000
Missouri River at Toston, Montana	216	0.29	3,718,000	1,091,000
	With Project		With Project	
Big Hole River at Reichle Reservoir Site	95	0.13	830,000	107,000
Jefferson River at Twin Bridges, Montana	219	0.30	1,195,000	356,000
Jefferson River above Three Forks, Montana	219	0.30	1,062,000	316,000
Missouri River at Toston, Montana	222	0.30	3,622,000	1,091,000

VI. ECONOMIC BENEFITS

At this time no need is foreseen for inclusion of storage for regulation of streamflow for the purpose of water quality control, therefore, no economic benefits have been assigned to the Jefferson-Whitehall Units. This conclusion is based on the following findings:

1. No need is foreseen at this time for improving present water quality.

2. The proposed project development will have no significant effect on water quality.

3. With or without project development minimum streamflows will be adequate for the assimilation of adequately treated municipal waste waters from projected populations in the study area.

4. For the purpose of maintaining water quality it is necessary that a pulp mill locating in the Three Forks area discharge its adequately treated wastes to the Missouri River. The streamflows required for assimilation of treated pulp mill wastes are met essentially 100 percent of the time in the Missouri River at Toston. Even with streamflow regulation there would be times when the required flows could not be met on the Jefferson, Beaverhead, and the Big Hole Rivers. The flows of the Madison and Gallatin Rivers will not be affected by the proposed projected development.

PART B - PUBLIC HEALTH ASPECTS

I. SUMMARY AND RECOMMENDATIONS

Summary

1. Project development will improve the economy and permit the establishment of a more healthful environment. Public health services are provided in the area by the Montana State Board of Health.

2. Recreational development contiguous to reservoirs will be partially regulated by the topographical features of the shoreline.

3. Temporary construction camps may be necessary to serve the contractor's employees.

4. As overall watershed management involves many interests, it is essential that the affect on public health be fully coordinated with State and/or local health departments.

5. Mosquitoes are the principal vectors which might be affected by the proposed project, although other insects and rodents may be involved.

6. Encephalitis is the most important mosquito-borne disease in the United States and in the proposed project area. Equine encephalitis cases occurred in one or more counties within the 7-county project area during 14 years of the 16-year period 1940 through 1955.

7. Mosquito production may occur in tributary embayments and other marginal areas of the reservoir where the topography is flat and the water is shallow, protected from wave action, and contains emergent vegetation or flotage.

Recommendations

Overall watershed management requires the cooperation of many interests to assure that development and activities will minimize the potential public health hazards associated with the proposed project. Every possible effort should be made to avoid creating conditions which will increase population of mosquitoes and other arthropods and rodents of public health importance. It is therefore recommended that the following be given due consideration in development of the Jefferson and Whitehall Units.

1. That the water users' organizations (e.g., Water Conservancy Districts) operating as the general administrative and contracting agency for the project should:

   a. Alert all water users of the potential public health hazards associated with using inadequately treated water for culinary purposes;

   b. Exert all possible precaution to exclude sewage effluents and barnyard drainage from project canals, laterals, and drains;

   c. Wherever and whenever possible assist the project inhabitants and communities in development of approved water and sewerage facilities;

   d. Operate and maintain project and facilities in accordance with established criteria.

2. That potential recreational areas be investigated and at least minimum water and sanitary facilities be provided in accordance with Montana State Board of Health.

3. That a sanitary survey of proposed construction campsites be made and all camps be provided with water and sanitary facilities in accordance with Montana State Board of Health regulations.

4. That recreational activities at reservoirs utilized as a source of public water supplies meet the requirements established by the Montana State Board of Health.

5. That person or persons responsible for a public water supply establish suitable controls over the use of watershed areas tributary to the supply to insure production of raw water meeting the quality requirements established by the Montana State Board of Health.

6. Where applicable, the principles and practices for prevention and control of vector problems associated with reservoirs outlined in Appendix F be adhered to in the design, construction, and maintenance of the project.

7. Where applicable, the principles and practices for prevention with elimination of mosquito sources associated with irrigation outlined in Appendix G be adhered to in the development, operating, and maintenance of the project.

II. PUBLIC HEALTH AND RELATED PROBLEMS

Public Health Services

Project development will improve the economy of the area so that local residents benefiting either directly or indirectly will be in a position to enjoy a higher standard of living. Among other necessities, this involves the establishment of a healthful environment. Some of the more important factors in creating such an environment include the development of safe and ample culinary water supplies, proper waste disposal facilities, and insect and rodent control measures.

Public health services are provided in the project area by the Montana State Board of Health.

Recreational Development

Concomitant with the development of water resources comes the increased use of lands adjoining reservoirs for recreational purposes. This presents major problems of sanitation involving those of coordination of multiple use policy and prevention of water pollution. The extent of recreational development, planned or spontaneous, immediately contiguous to reservoirs will be partially regulated by the topographical features of the shoreline. Also, a receding shoreline during the irrigation season, together with an accumulation of mud deposits above the water level, will create hazardous and undesirable conditions for some water-based recreational activities.

Construction Phase of Project

Limited housing accommodations are available in the vicinity of construction sites in the Three Forks Division to serve the contractor's employees during the construction phase of the project. Under these conditions a temporary construction camp may be necessary. Prior to selection of a campsite a sanitary survey of the proposed area should be made by the Montana State Board of Health or the Public Health Service to assist in solving of problems which may be encountered with the installation of water and sanitary facilities.

Water supplies and sanitary facilities required in connection with temporary construction camps and with permanent housing for reservoir attendants should comply with the requirements of the Montana State Board of Health so as to eliminate potential health hazards.

Sanitary Aspects of Watershed Management

An overall watershed management involves many interests. It is considered essential that proposed developments and activities on watersheds pertaining to public health aspects be fully coordinated with state and/or local health departments. These matters should be mutually considered prior to the actual development of the watershed and issuance of permits.

Adequate and safe water and sanitary waste disposal facilities, in accordance with state and/or local health agency standards, should be provided in public use areas to serve camping, picnicking, and other recreational uses. Water and sanitary facilities for private dwelling sites should also meet the established health standards. The effectiveness of the sanitation program should be evaluated periodically by a detailed sanitary survey in conjunction with laboratory analyses of water samples collected from surface and/or ground water in the watershed.

On reservoirs constructed primarily to serve as a source for a municipal water supply, extreme caution should be exercised in considering recreational use of the reservoir. This also involves the possibility of additional pollution entering the water supply and the matter of aesthetics.

Preliminary Vector Evaluation

Anticipated Effects of the Proposed Project on Vector Problems

Mosquitoes are the principal vectors which might be affected by the proposed project, although other insects and rodents may also be involved. Several species of mosquitoes of public health importance including Culex tarsalis, the encephalitis mosquito, and the vicious-biting Aedes vexans and Aedes dorsalis may be produced in large numbers in the area when suitable aquatic habitats are present. Basic information concerning pertinent biological characteristics of these mosquitoes is given in Appendix B.

Encephalitis, commonly known as sleeping sickness or brain fever, is now the most important mosquito-borne disease in the United States and the area in which the proposed project is located. Records of the U. S. Department of Agriculture show that equine encephalitis cases occurred in one or more counties within the seven-county project area during 14 years of the 16-year period, 1940 through 1955, for which records are available. Although no outbreaks of human encephalitis have been reported in the general area of the proposed project, the records of equine encephalitis cases indicate a potential for the disease among humans in the area. Additional information concerning the public health and socio-economic importance of mosquito and other vector problems associated with water resources developments is presented in Appendix C.

Portions of the proposed reservoirs that have shorelines with little or no vegetation and are exposed to wave action will be unfavorable for the production of mosquitoes and other aquatic insects of public health importance. Mosquito production may occur in tributary embayments and other marginal areas of the reservoirs where the topography is flat and the water is shallow, protected from wave action, and contains emergent vegetation or flotage. Information concerning reservoir preparation, maintenance, and water level management in relation to mosquito prevention and control is presented in Appendix D. Mosquito production may also occur in the percolation ponds used for ground-water recharge if the ponds are shallow and contain emergent vegetation or debris.

The development of water-related recreational and other public use areas in conjunction with the proposed reservoirs may result in the exposure of humans to vectors of terrestrial origin including anthropods such as ticks, fleas, and flies, and rodents such as ground squirrels, chipmunks, rats, and mice. In order to minimize public health hazards at waterside recreational areas, appropriate prevention and control measures for both aquatic and terrestrial vectors should be carried out.

The provision of a larger supply of water for lands presently irrigated and the development of additional new irrigated areas may aggravate existing mosquito sources and create new aquatic habitats favorable for mosquito production unless appropriate prevention and control measures are provided and continued as a part of the regular operation and maintenance. Pertinent information concerning the relationships between irrigation and mosquito sources is presented in Appendix E.

By making provision for the prevention and control of man-made vector sources, the overall benefits of the proposed project can be greatly increased.

Responsibility for Vector Control

Responsibility for vector prevention and control is normally associated with land ownership or operating rights. Therefore, the agency, group, or individuals responsible for various aspects of the proposed project should be prepared to accept full responsibility for the prevention and control of vector problems resulting from the design, construction, operation, or maintenance of the project.

BIBLIOGRAPHY

1. U. S. Bureau of Reclamation, Region 6, Report on Three Forks Division, Upper Missouri: Projects Office, Great Falls, Montana, September 1958

2. U. S. Department of Interior, Fish and Wildlife Service, Fish and Wildlife Resources and the Three Forks Division, Portland, Oregon

3. U. S. Geological Survey, Geology and Ground Water Resources of the Gallatin Valley, Gallatin County, Montana, WSP 1482

4. U. S. Geological Survey, Geology and Occurrences of Ground Water in the Townsend Valley, Montana, WSP 1360-C

5. Montana State Board of Health and Montana State Fish and Game Department, Three Forks Area Water Quality Study, Progress Report 1, 10/59-9/60 and Progress Report 2, 10/60-9/61

6. Montana State Board of Health, Stream Classification for Missouri River and Tributaries, Progress Report 61-2, approved 5/27/61

7. Water Supply and Waste Water Disposal, 1956, Fair and Geyer

8. California Water Quality Control Board, Water Quality Criteria, Second Edition, 1963

9. U. S. Department of Agriculture Forest Service, Research Note, Log Production in Idaho and Montana, No. 54 and 55, April 1958.

10. State of Montana Bureau of Mines and Geology, Bulletin 11, Summary of Montana Mineral Resources, by V. M. Sahinen and F. A. Crowley. Printed by Montana School of Mines, Butte, Montana, May 1959. Reprinted December, 1959

11. Forest Resources of South Central Montana, by T. L. Finch, W. C. Hodge and M. E. Metcalf. U. S. Department of Agriculture Forest Service. Station Paper No. 23, April 1950, 19 p.

12. Resources Factors Affecting the Feasibility of Pulp Mills in Eastern Montana, by S. Blair Hutchison and John H. Wikstrom. U. S. Department of Agriculture Forest Service. Station paper No. 34, July 1952.

13. Forest Service, Washington, D. C. 2410 Plans. Timber Management Plans, Montana, Region 1.

14. U. S. Census of Agriculture 1945, 1950, 1954 and 1959, Montana Counties, Volume 1, Parts 37 and 38, U. S. Department of Commerce, Bureau of the Census

15. U. S. Department of Commerce, Bureau of the Census. Montana Census of Manufactures, 1947, 1954 and 1958

16. U. S. Department of Commerce, Bureau of the Census. United States Census of Population for Montana, General Social and Economic Characteristics, 1940, 1950 and 1960

17. 1960 Census of Population, Characteristics of Population, Number of Inhabitants, U. S. Department of Commerce, Bureau of the Census

18. Rudolfs, Willem, Industrial Wastes, Their Disposal and Treatment, "Pulp Paper, and Paperboard", Gehm, H. W., 1953

APPENDICES

APPENDIX "A"
Stream Classification (6)

Stream	Location	Present Use 1/	Classification 2/
Beaverhead River and Tributaries except Rattlesnake Creek and Ruby River	Source to Jefferson River	Ag, F&R, PS	B, C, D, E
Rattlesnake Creek and Tributaries	Source to City of Dillon Water Supply Intake	WSp, Ag, F&R	A, C, D, E
	Dillon Water Supply Intake to Beaverhead River	Ag, F&R	B, C, D, E
Ruby River and Tributaries except Indian Creek	Source to Beaverhead River	Ag, F&R, PS	B, C, D, E
Indian Creek and Tributaries	Source to Sheridan Water Supply Intake	WSp, Ag, F&R	A, C, D, E
	Sheridan Water Supply Intake to Ruby River	Ag, F&R	B, C, D, E
Big Hole River and Tributaries	Source to Confluence with Jefferson River	Ag, F&R, PS	A, C, D, E
Jefferson River and Tributaries except Whitetail Creek and Boulder River	Confluence of Big Hole and Beaverhead Rivers to Missouri River	Ag, F&R, PS	B,C, D, E
Whitetail Creek & Tributaries	Source to Jefferson River	Ag, F&R, PS	B, C, D, E
Boulder River & Tributaries except Basin Creek	Source to Jefferson River	Ag, F&R, PS	B, C, D, E
Basin Creek & Tributaries	Source to Basin Water Supply Intake	WSp, Ag, F&R	A, C, D, E
	Basin Water Intake to Boulder River	Ag, F&R	B, C, D, E

Madison River & Tributaries	Source to Missouri River	Ag, F&R, PS	B, C, D, E
West Gallatin River & Tributaries	Source to East Gallatin River	WSp, Ag, F&R	A, C, D, E
East Gallatin River & Tributaries except Bozeman, Bridger and Hyalite Creeks	Source to West Gallatin River	Ag, F&R, PS, IW	B, C, D, E
Bozeman Creek & Tributaries	Source to Bozeman Water Intake	WSp	A, C, D, E
	Bozeman Water Intake to East Gallatin River	--	B, C, D, E
Bridger Creek & Tributaries except Lyman Creek	Source to East Gallatin River	Ag, F&R	B, C, D, E
Lyman Creek	Source to Bridger Creek	WSp	A, C, D, E
Hyalite Creek & Tributaries	Source to Bozeman Water Intake	F&R, Ag, WSp	A, C,D, E
	Bozeman Water Intake to East Gallatin River	F&R, Ag	B, C, D, E
Gallatin River & Tributaries	Confluence of East and West Gallatin Rivers to Missouri River	Ag, F&R	B, C, D, E
Missouri River Mainstem & Tributaries	Confluence of Madison, Jefferson, and Gallatin Rivers to Canyon Ferry Dam	WSp, Ag, F&R, IW, PS	B, C, D, E

1/ Ag - Agriculture, F&R-Fishing and Recreation, PS - Public Sewage, WSp - Public Water Supply, IW - Industrial waste

2/ A - Simple disinfection adequate to produce potable water supply
B - Treatment equivalent to coagulation, sedimentation, filtration & disinfection to produce potable water
C - Acceptable for bathing, swimming and recreation
D - Acceptable for fish and other aquatic life
E - Acceptable for agricultural and industrial water supply

Biology of Mosquitoes

This discussion is intended to provide only basic information concerning some of the more pertinent biological characteristics of mosquitoes commonly associated with water resource developments. These mosquitoes represent four important genera or groups: Anopheles, Culex, Aedes, and Psorophora. All mosquito species have four distinct stages in their life cycle: the egg, the larva ("wiggler"), the pupa ("tumbler"), and the adult. A characteristic common to all mosquitoes is that they live in water continuously from the time the eggs hatch until the adults emerge. The aquatic stages generally occur in shallow water with an abundance of vegetation and flotage, and where they are protected from wave action. They do not occur in the deep open waters of lakes, ponds, or streams.

On the basis of egg-laying habits, mosquitoes may be divided into temporary-water and permanent-water species. The Aedes and Psorophora are temporary water breeders which deposit their eggs on the moist soil of areas where surface water has receded. Hatching of the eggs is stimulated by subsequent floodings. The eggs may remain dormant for long periods, sometimes for several years if conditions are unfavorable for hatching. Normally, the eggs hatch more or less simultaneously soon after they are flooded. In contrast, the Anopheles and Culex usually lay their eggs on the surface of permanent and semipermanent bodies of water. The eggs usually hatch within a few days after oviposition. For both the temporary-water and permanent-water mosquitoes, time between hatching of eggs and emergence of adults varies with species and environmental conditions, especially water temperature. Development of the aquatic stages may be completed in as little as four days in hot weather while several weeks may be required in cool weather. Aedes and Psorophora mosquitoes generally develop more rapidly than the Anopheles and Culex.

Adult mosquitoes mate soon after emergence and the females begin seeking blood meals, which most species require before laying eggs. The biting habits of adult mosquitoes vary with species. Anopheles and Culex mosquitoes feed mainly at night while Aedes and Psorophora species feed both at night and in the daytime. Most species exhibit a peak of biting activity during a one- or two-hour period immediately after sundown. The Aedes and Psorophora species are aggressive and vicious biters of both man and livestock. Culex tarsalis, a vector of encephalitis, feeds readily on a wide range of hosts including man, wild and domestic birds, and livestock.

The flight range of mosquitoes varies widely with species and environmental conditions. The direction and distance of travel are greatly influenced by availability of food, shelter, and wind conditions. Availability of food is probably the most important factor influencing the movement of mosquitoes in many areas. If an adequate food supply is close to

the production sites, adult mosquitoes probably will not travel far from their sources. On the other hand, mosquitoes may travel several miles when adequate food supplies are not available nearer their larval habitats. The normal flight range of the Anopheles and Culex mosquitoes is usually considered to be about one mile, although recent studies have shown that certain species such as C. tarsalis may travel several miles under certain environmental conditions. Most Aedes and Psorophora species are strong fliers and are known to range several miles from their larval habitats.

APPENDIX C

Public Health and Socio-Economic Importance of Vector Problems Associated with Water Resource Developments

Several groups of arthropods and rodents associated with the development and utilization of water resources may create serious public health and socio-economic problems. These include species that are vectors of disease organisms or serve as reservoirs of these organisms or which otherwise interfere with man's health and welfare.

Mosquitoes

Approximately a dozen species of mosquitoes of public health and socio-economic importance may be produced in habitats associated with irrigation, impoundments, and other water resource developments. Encephalitis, commonly known as sleeping sickness or brain fever, is now the most important mosquito-borne disease in the United States. Mosquitoes obtain the encephalitis viruses from wild vertebrates and then transmit them to horses and humans. There are no effective chemotherapeutic measures for preventing or treating human cases; and some individuals, particularly children, who recover from encephalitis often suffer permanent mental disability. Three principal types of mosquito-borne encephalitis occur in the United States. Eastern encephalitis (EE) occurs mainly in the Atlantic and Gulf Coast States from New Hampshire to Texas, but sometimes extends as far inland as Wisconsin. St. Louis encephalitis (SLE) occurs chiefly west of the Mississippi River and in several of the Central States. The third type, western encephalitis (WE), is confined primarily to the states west of the Mississippi River.

Culiseta melanura and several species of Aedes mosquitoes are believed to be involved in the transmission of EE. The principal vector of both WE and SLE in the Far West is Culex tarsalis, a mosquito which is widely distributed west of the Mississippi River. In the Central States, Culex pipiens and Culex quinquefasciatus are believed to be important in the transmission of SLE. Aedes and other mosquitoes may also be involved as secondary vectors of encephalitis. Both western and St. Louis encephalitis are endemic in many western areas, and outbreaks of WE among horses and of WE and SLE among humans have been rather widespread. In recent years, outbreaks of encephalitis have occurred in irrigated areas in the Texas High Plains (1956), in the Intermountain States (1957), in the Lower Rio Grande Valley (1957), in Utah and New Mexico (1958), and in Wyoming (1960).

The occurrence of malaria outbreaks as a result of improperly prepared reservoirs in the Southeastern States is well documented. Malaria has also been associated with irrigation in several states including California, New Mexico, Texas, and in the rice-growing areas of the Mississippi Delta. This disease has been almost eradicated from the United States; and at present, there is no significant malaria trans-

mission anywhere in the Nation. The malaria vectors (Anopheles quadrimaculatus in the East and Anopheles freeborni in the West) are still prevalent in some areas where favorable habitats are present. These mosquitoes constitute a potential hazard for the establishment of new foci of malaria transmission, particularly in situations where the disease may be reintroduced from foreign countries. This was well illustrated at Lake Vera in California during the summer of 1952, where 35 cases of malaria occurred among Camp Fire Girls. The source of their infections was traced to a soldier who had an attack of malaria while camping at the lake.

Several vicious-biting species including Aedes vexans, Aedes dorsalis, and Aedes nigromaculis may be produced in habitats associated with irrigation and other water resource projects. These mosquitoes often create public health problems aside from the transmission of specific diseases. Such health hazards are illustrated by the results of surveys made by the U. S. Public Health Service in irrigated areas in northern Montana. In three-fourths of the families surveyed, mosquitoes severely annoyed both adults and children and interfered with their normal outdoor activities during the summer months. Mosquito bites caused some degree of injurious reaction in 8 out of 10 people interviewed; and in one section, 40% of the individuals examined by the physician showed evidence of secondary infection of mosquito bites. Some individuals, particularly children, frequently required medical attention and sometimes even hospitalization for treatment of secondary infections and occasional allergic reactions caused by mosquito bites.

In addition to their public health importance, mosquitoes often create other serious problems in both rural and urban areas. Their vicious biting reduces the efficiency of farm workers and sometimes hinders the harvesting of crops. Dense populations of attacking mosquitoes have been reported to kill livestock. The constant attacks of even moderate populations of these insects may reduce the vitality of farm animals and prevent proper feeding, thereby causing reduced weight gains and lower milk and egg production. Mosquitoes are vectors of encephalitis, anaplasmosis, fowl pox, and several other important diseases of animals. These diseases kill large numbers of farm animals each year. Together, mosquito annoyance and mosquito-transmitted diseases undoubtedly result in losses of millions of dollars to farmers every year.

Large numbers of biting mosquitoes also cause serious economic losses by reducing the efficiency of industrial workers, lessening the value of real estate, restricting outdoor recreational activities, and reducing attendance at outdoor business establishments such as drive-in theatres and eating places.

The economic magnitude of the irrigation-mosquito problem alone is illustrated by expenditures for abatement of these insects. For example, in California over $5,000,000 is spent annually to control encephalitis and other irrigation mosquitoes and it has been estimated that at least

twice this amount would be required to provide adequate control throughout the State. Approximately $200,000 is spent each year for mosquito abatement in a few irrigated areas in Utah. Many urban communities in other western irrigated areas spend large sums of money each season for chemical control to provide partial protection from mosquitoes. Individual families also spend sizable amounts of money each summer for household sprays, mosquito repellents, livestock sprays, and medicine for treatment of mosquito bites. The total cost of controlling irrigation mosquitoes, together with the other serious economic losses they cause, runs into many millions of dollars each year. Thus, mosquitoes are a major economic liability in many irrigated areas.

Other Aquatic Insects

Several other groups of aquatic insects may be produced in sufficient numbers in habitats associated with water resource projects to create public health and economic problems. Deer flies and horse flies (Tabanidae) are produced along the margins of impoundments and in seeps and marshes in irrigated areas. These insects are vicious biters of both man and livestock and are sometimes involved in the transmission of diseases such as tularemia and anthrax. Some species of small gnats of the family Heleidae are also vicious biters and often produce severe reactions and vesicular lesions. These gnats are produced in damp areas of many irrigated valleys as well as salt marshes and other wetland areas. In certain areas, black flies (Simuliidae) plague both man and livestock with their irritating and painful bites. They are normally produced in streams but sometimes occur in large numbers in irrigation conveyance systems. The small nonbiting midges (Tendipedidae) and the phantom midges (Chaoborinae) are another group of pestiferous insects which may be produced in impounded water. These insects are attracted to lights in tremendous numbers and cause severe human annoyance. An example is the Clear Lake gnat, Chaoborus astictopus, which creates serious problems at the resort areas in Lake County, California.

Terrestrial Arthropods and Rodents

Each summer, many millions of people visit picnic sites, campgrounds, cabins, and other water-related recreational facilities along the shores of reservoirs. In addition to mosquitoes and other insects of aquatic origin, these people are often exposed to terrestrial arthropods such as ticks, mites, fleas, and flies and rodents including ground squirrels, rats, mice, and chipmunks. The public health importance of these arthropods and rodents involves a number of human diseases including Rocky Mountain spotted fever, Colorado tick fever, tularemia, relapsing fever, tick paralysis, typhus, plague, bacillary dysentery, and typhoid. The bites of certain arthropods also cause considerable irritation, discomfort, and annoyance.

APPENDIX D

Reservoir Preparation, Maintenance, and Water Level Management in Relation to Mosquito Prevention and Control

Man-made impoundments range in size from large multipurpose reservoirs with thousands of acres to small farm ponds of less than an acre. Mosquito-producing conditions associated with both large and small impoundments are basically similar but vary greatly in magnitude. They include emergent vegetation and/or floating debris in shallow water areas which are protected from wave action; undrained depressions, borrow pits, sloughs, and marshes within the summer fluctuation zone; and rising or constant pool levels which cause the water to remain in relatively flat areas with vegetation for more than four or five consecutive days during the mosquito production season. Several species of Anopheles and Culex mosquitoes, including Culex tarsalis, are frequently produced in impoundments that have protected shallow water areas with emergent vegetation and/or flotage. The flat vegetated areas of reservoirs and ponds, which are alternately inundated and exposed by fluctuating water levels, may also be highly favorable for the production of several species of Aedes and Psorophora mosquitoes. Aedes vexans is one of the most common and widespread of these species. It is almost axiomatic that reservoirs and ponds which are free of vegetation and flotage do not produce mosquitoes.

It is often difficult to control mosquito production on a reservoir that has not been properly prepared prior to impoundage. Clearing and drainage are the principal reservoir preparation measures for mosquito prevention and control. The overall objective of these measures is to prevent or minimize the development of favorable mosquito-producing habitats in any portion of the reservoir which is within flight range of human population.

Clearing includes removal of trees, underbrush, vines, fences, and debris from the reservoir basin. For mosquito control purposes, the normal summer fluctuation zone should be completely cleared except for isolated trees and sparse vegetation located along abrupt shorelines that will be exposed to wave action. It is not necessary to clear timber from the deeper portions of the reservoir basin where it will be completely submerged at normal summer minimum pool elevation. Timber rooted below the normal summer minimum pool level but extending above that elevation may be felled and securely tied down in lieu of disposal. This practice sometimes has advantages in fisheries management. Where clearing operations extend over several seasons, it is sometimes necessary to remove regrowth from the normal summer fluctuation zone immediately prior to impoundage.

Borrow pits, depressions, marshes, and sloughs which will be flooded when the reservoir is at maximum pool level and which will retain water at lower pool levels may be serious mosquito sources. Drainage ditches

should be provided for all such areas, particularly those located within the normal summer fluctuation zone. These ditches should insure complete drainage of the areas when the reservoir recedes and permit fluctuation of water levels in them when the reservoir is at higher elevation. Such drainage ditches may also serve to prevent the stranding of fish when the lake recedes. Logs, drift, and other debris should be removed from natural drainageways and existing ditches where such work is indicated for mosquito prevention and control. Permanent shoreline improvement measures can sometimes be employed to eliminate mosquito-producing areas in reservoirs when the normal summer fluctuation zone is limited to a few feet.

Since the effectiveness of naturalistic, preventive, and permanent mosquito control measures is determined by the amount of clean water surface they create, it is essential that ponds and reservoirs be properly maintained after they have been impounded. Furthermore, maximum mosquito control benefits from water level management can be realized only when impoundments are properly prepared and maintained. Several phases of water level control, such as flood surcharge, constant level pool, cyclical fluctuation, and/or seasonal recession, can sometimes be adapted to various types of impoundments in order to minimize conditions favorable for mosquito production. Certain phases may be used to control vegetation and flotage or they may be used primarily to destroy mosquito larvae. A flood surcharge above the upper normal pool level for a few days in the spring prior to the mosquito production season followed by a sharp drawdown is effective in stranding objectionable flotage. The invasion of marginal vegetation can be limited by holding the reservoir at a constant level during the early spring growth period. This phase is especially important since it increases the effectiveness of subsequent fluctuation and/or recession. Seasonal water level recession alone or in combination with periodic fluctuation is an effective control measure since it provides a clean shoreline which is unfavorable for mosquito production. In some irrigation storage reservoirs, the normal water releases during the growing season usually result in a drawdown that keeps the pool level below encroaching marginal vegetation, thereby providing a clean shoreline that is unfavorable for mosquito production.

Recreational areas, especially those with facilities where people may remain overnight, should be located along sections of the reservoir which have the lowest potential for the production of mosquitoes and other aquatic insects of public health importance. Proper consideration should also be given to terrestrial vector problems in selecting recreational sites. Where necessary, full provision should be made for the prevention and control of both types of vector problems.

APPENDIX E

Relationships Between Irrigation and Mosquito Sources

The production of mosquitoes and other aquatic insects of public health importance occurs in many western irrigation areas, particularly where the water is applied by surface methods. Natural mosquito habitats are present in most irrigated areas, but usually man-made mosquito sources are far more important. These man-made aquatic habitats are frequently caused by the same faulty irrigation and drainage practices that result in serious soil and water problems such as excessive water losses, waterlogging, erosion, salt and alkali accumulations, damage to soil structure, leaching of plant nutrients, and reduced crop yields. Some of the "on-field" and "off-field" mosquito sources commonly associated with irrigation in the west are briefly discussed in the following sections.

On-Field Mosquito Sources

Prolific mosquito production occurs in low areas on fields used for pastures, hay meadows, and other close-growing forage crops where irrigation water often remains ponded long enough for the larvae to mature. Mosquitoes are sometimes produced on fields planted to irrigated row crops such as cotton, but usually ponded water is not present on these fields long enough for the aquatic stages to complete their development. Surface water must be present for at least 4 or 5 days in order for the aquatic stages to mature and produce adult mosquitoes. Rice is the only field crop that thrives when flooded this long. Observations in several areas have shown that when irrigation water is ponded on pastures and hay meadows long enough to produce mosquitoes, the desirable forage grasses and legumes are frequently killed and replaced by undesirable wetland plants. Thus, the extended flooding which is conducive to mosquito production is unfavorable for satisfactory growth of the common field crops.

In California, tremendous numbers of Aedes nigromaculis are produced in the ponded areas on irrigated pastures. Some of these pastures are irrigated 10 to 15 times from April through October and a brood of mosquitoes may be produced in the ponded water that remains after each irrigation. Investigations in the Milk River Valley of northern Montana showed that over two-thirds of all mosquito production (mostly Aedes dorsalis and A. vexans) on a 5,000-acre study area occurred in ponded areas on irrigated alfalfa fields, pastures, and western wheat grass meadows. In this valley, the irrigation water frequently remains ponded on the hay meadows long enough to produce Culex tarsalis, the encephalitis mosquito. Studies in Nebraska showed that large numbers of both C. tarsalis and Aedes mosquitoes are produced in ponded areas on irrigated pastures and hay meadows along the North Platte River. The use of irrigated mountain meadows for the production of hay and supplemental grazing of livestock is widespread in the Rocky Mountain

States. In many of the mountain valleys, the bottomland meadows are flooded almost continuously throughout the spring and early summer months. Ponding also occurs in numerous low areas following irrigation later in the season. The extensive aquatic habitats that occur on many irrigated mountain meadows produce tremendous numbers of encephalitis and other irrigation mosquitoes.

In addition to the depressions on irrigated fields, water sometimes remains ponded in the field laterals and drains long enough to produce encephalitis and other irrigation mosquitoes. This type of mosquito source occurs most often in areas having fine textured soils and poor underdrainage. Field laterals and drains that contain excessive amounts of vegetation are more favorable for mosquito production. Mosquitoes may also be produced in the residual water in various hydraulic structures, such as drops in ditches, particularly when they contain tumbleweeds and other debris. Mosquito production in hydraulic structures is usually of minor importance in comparison with that which occurs in other types of "on-field" aquatic habitats.

Rice fields constitute a special type of "on-field" mosquito source, since the flooding used for growing rice is very favorable for mosquito production. In rice fields of the Mississippi Delta and Gulf Coast areas, large numbers of Psorophora confinnis and Psorophora discolor are produced by intermittent irrigation; and Anopheles quadrimaculatus, the malaria mosquito, is produced in the constantly flooded rice fields. Rice fields in California are usually flooded throughout the growing season and they provide favorable aquatic habitats for production of Culex tarsalis, the encephalitis mosquito, and Anopheles freeborni, the western malaria mosquito. Large numbers of A. nigromaculis and A. boreali mosquitoes are frequently produced by the initial flooding of rice fields in California.

Off-Field Mosquito Sources

In many western irrigated areas, widespread and prolific mosquito production occurs in a variety of aquatic habitats located outside the boundaries of irrigated fields. These mosquito sources include roadside ditches, borrow pits, depressions on nonirrigable land, and numerous other undrained areas that are flooded by surface runoff from irrigated fields and other excess irrigation water. Such aquatic habitats often contain dense vegetation which makes them more favorable for mosquito production. The semipermanent and permanent water areas are highly favorable for C. tarsalis, the encephalitis mosquito. Those with fluctuating water levels produce large numbers of this mosquito as well as several vicious-biting Aedes species.

The types of "off-field" habitats just described accounted for more than one-fourth of the total mosquito production on a 5,000-acre study area in the Milk River Valley of northern Montana. In the North Platte Valley of western Nebraska, wasteland areas, roadside ditches, borrow

pits and other undrained areas flooded by runoff from irrigated fields and overflow from conveyance systems were found to be important sources of both C. tarsalis and Aedes mosquitoes. Playas or land-locked depressions, flooded by runoff from irrigated fields, were responsible for three-fourths of all mosquito production on study areas in the Texas High Plains. These playas produced large numbers of C. tarsalis and several other species of irrigation mosquitoes. In certain western areas, large nonirrigable areas are wildly flooded with excess irrigation water for use by ducks and other waterfowl. Such areas are highly favorable for the production of tremendous numbers of Aedes mosquitoes. Several of the abatement districts in California and Utah spend large sums each year to control mosquitoes produced on waterfowl areas of this type.

Mosquito sources are often associated with the main irrigation conveyance systems, portions of which are sometimes located on nonirrigable lands. A large amount of irrigation water is often lost by seepage and leakage through the beds and banks of unlined canals and laterals which are located in pervious material. In areas having poor underdrainage, these seepage losses alone or in combination with deep percolation from irrigated fields often result in marshes and ponded water in roadside ditches, borrow pits, and other areas. In many western irrigated areas, aquatic habitats created by seepage produce large numbers of mosquitoes. Permanent and semipermanent seepage areas have been found to be especially favorable for the production of C. tarsalis, a vector of encephalitis. Large numbers of Aedes mosquitoes are also produced in seepage areas that have fluctuating water levels.

Mosquito production may also occur in various other "off-field" aquatic habitats associated with the main irrigation conveyance systems. These mosquito sources include flooded areas resulting from overflow of poorly maintained canals and laterals; ponded areas where conveyance channels block natural drainageways; residual water in turnouts, stilling basins, and other hydraulic structures; surface pools created by leakage from water control structures; and residual water in conveyance channels during nonoperational periods. Although these types of aquatic habitat contribute to the total mosquito problem, they are generally of less importance than those caused by seepage and the numerous other "off-field" mosquito sources.

APPENDIX F

Principles and Practices for Prevention and Control of Vector Problems Associated with Reservoirs

I. Prevention and Source Reduction Measures

A. For Mosquitoes and Other Aquatic Insects

1. All borrow pits and other potential ponding areas associated with construction of the dam, relocation of highways or roads, etc., which are located above maximum pool level should be made self-draining.

2. Prior to impoundage, the reservoir basins should be prepared as follows:

   a. The normal summer fluctuation zone of the permanent pool should be completely cleared except for isolated trees and sparse vegetation along abrupt shorelines which will be exposed to wave action.

   b. Dense stands of timber rooted below the normal summer minimum pool level but extending above that elevation should be cleared. In some situations, such timber may be felled and securely tied down in lieu of disposal.

   c. Borrow pits, depressions, marshes, and sloughs which will be flooded by the reservoir at maximum pool level and which would retain water at lower pool levels should be provided with drains to insure complete drainage or fluctuation of water within them.

   d. If the summer fluctuation zone of the permanent pool is limited to a few feet, consideration should be given to "building out" mosquito-producing areas located within flight range of population groups or recreational areas through the use of measures such as deepening and/or filling. This would minimize the need for repetitive measures for controlling vegetation and mosquito production.

3. After impoundage, the following maintenance measures should be carried out in all potential mosquito-producing areas located within flight range of human population groups or recreational areas frequented by significant numbers of persons:

   a. All dense vegetation should be removed periodically from flat, protected areas within the normal summer fluctuation zone of the permanent pool.

b. Vegetation, debris, and flotage should be removed periodically from all drains to insure free flows.

4. Water level management to minimize conditions favorable for mosquito production should be used to the maximum degree permitted by the primary purposes of the reservoir. This will minimize the need for repetitive measures for controlling vegetation and mosquito production.

5. As a general principle, waterside recreational areas, particularly those which have facilities for overnight human occupancy, should be located along sections of the reservoir which have a low production potential for mosquitoes and other aquatic insects of public health importance.

B. For Terrestrial Arthropods and Rodents at Recreational Areas

1. Proper storage, collection, and disposal of refuse should be practiced in order to prevent and control flies, wasps, other noxious insects, rats, wild rodents, and other small mammals.

2. All buildings should be rodentproofed at recreational areas where rodents are prevalent which may create public health hazards.

3. Debris, rubbish, and other materials which may serve as harborage for rodents and other small mammals should be removed periodically.

4. Brush and weeds along paths, trails, roadways, and other areas of frequent use by visitors should be removed in order to reduce the likelihood of tick infestation.

II. Supplemental Chemical Control Measures

In situations where adequate vector control is not obtained through prevention and source reduction measures, provision should be made for supplemental use of insecticides and rodenticides to achieve the desired level of control.

III. Vector Appraisal

Arrangements should be made for carrying out a routine program of vector appraisal as a part of normal operations of the reservoir and associated recreational areas. Inspections for adult and larval mosquitoes and other vectors are essential for planning and evaluating control measures and for adjusting control programs to meet temporary or emergency situations.

Principles and Practices for Prevention and Elimination of Mosquito Sources Associated with Irrigation

A. Project Conveyance and Distribution Systems

1. Lining or other satisfactory seepage control measures should be provided for all sections of canals and laterals located in porous material where excessive leakage would result in waterlogged areas, seeps, and ponds.

2. Drains should be installed to prevent ponding of excess irrigation water and natural runoff along the upper side of canals and laterals. All drainage crossing or inlet structures should be placed on grade to avoid ponding.

3. Borrow areas should be self-draining to keep them from retaining ponded water.

4. Where possible, provision should be made to prevent turnouts and other hydraulic structures from retaining residual water when they are not being used.

5. Effective measures should be provided to prevent ponding of leakage from water control strucutres.

6. Every effort should be made to establish delivery schedules which will provide farmers with adequate but not excessive amounts of water at proper intervals to insure efficient irrigation of the crops concerned.

7. Vegetation and debris which would retard normal flows should be periodically removed from conveyance channels, water control structures, and drains.

B. Project Drainage Systems

1. Trunk drainage systems should be installed to insure complete removal and proper disposal of excess irrigation water, natural runoff, and seepage from both irrigable and nonirrigable lands affected by the distribution and use of irrigation water on the project.

2. Drainage ditches should be designed, constructed, and maintained so as to minimize ponding in the channels and to insure free flows at all times.

3. Provision should be made to prevent water from ponding behind spoil banks.

4. Underdrains, culverts, inlets, etc., should be placed on grade to prevent ponding.

C. Irrigated Farms

1. The sponsoring agency and other organizations concerned with irrigation agriculture or mosquito control should do everything possible to encourage irrigation farmers to use the following irrigation and drainage practices which will prevent or minimize mosquito sources:

   a. The farm supply system, drainage system, and field layouts should be properly fitted to the topography, soil, water supply, crops to be grown, and irrigation methods to be used.

   b. All surface irrigated fields should be properly leveled or graded to provide for efficient water application and removal of excess water without ponding.

   c. An adequate drainage system should be provided for removal of excess water from all portions of the farm.

   d. Irrigation methods should be used which will provide optimum irrigation efficiencies.

   e. Application of irrigation water should be limited to that required to fill the crop root zone plus unavoidable losses and excess water needed to prevent upward movement of salts.

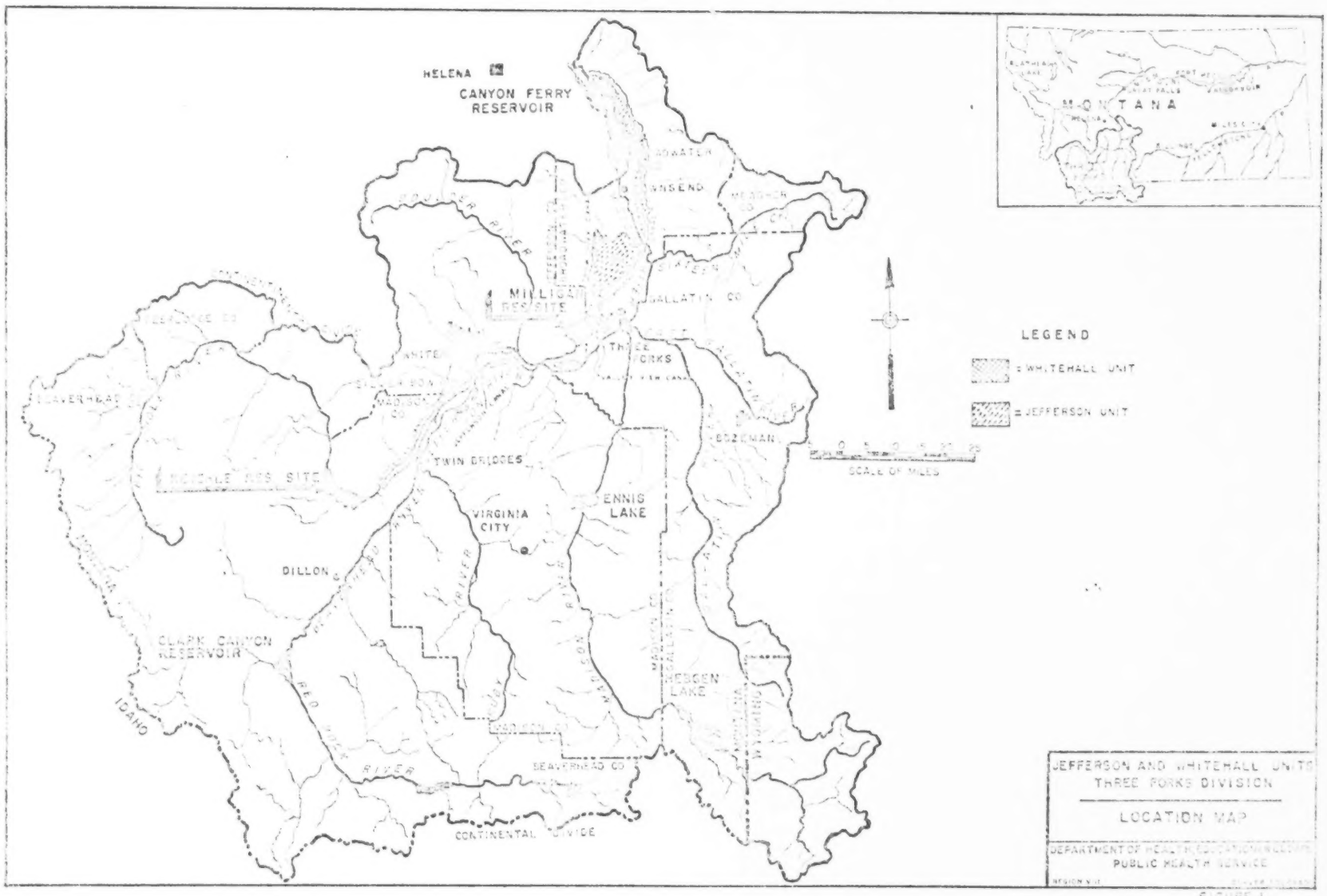

HELENA
CANYON FERRY RESERVOIR
MISSOURI RIVER
MILLER CREEK SITE
BOULDER RIVER
GALLATIN CO
THREE FORKS
BOZEMAN
TWIN BRIDGES
MADISON CO
BEAVERHEAD CO
MADISON RIVER
RUBY RIVER
VIRGINIA CITY
ENNIS LAKE
DILLON
CLARK CANYON RESERVOIR
IDAHO
RED ROCK RIVER
HEBGEN LAKE
BEAVERHEAD CO
CONTINENTAL DIVIDE
MONTANA
LEGEND
= WHITEHALL UNIT
= JEFFERSON UNIT
SCALE OF MILES
JEFFERSON AND WHITEHALL UNITS
THREE FORKS DIVISION
LOCATION MAP
DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
PUBLIC HEALTH SERVICE
REGION VIII

FIGURE 1

G-3